

## G E O R G E R.

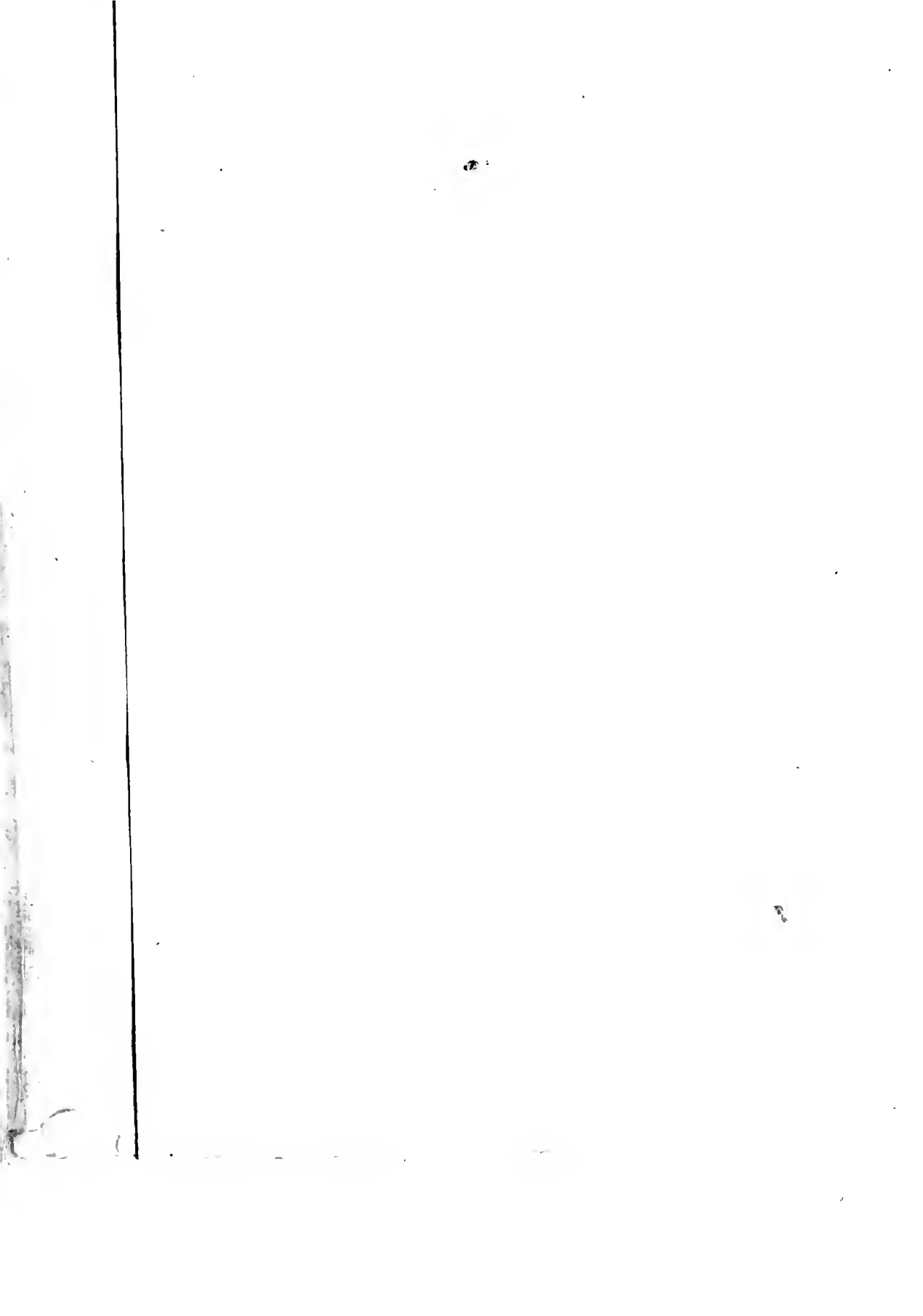
**W**HEREAS our trusty and well-beloved WILLIAM LEWIS, of *Kingston*, in our County of *Surrey*, M. B. has, by his Petition, humbly represented unto Us, that he hath been, for upwards of Fourteen Years, engaged in making Experiments, and collecting Materials, for a Work, entitled “*COMMERCIVM PHILOSOPHICO-TECHNICVM*, or, The “*PHILOSOPHICAL COMMERCE OF ARTS*; designed as an Attempt to “promote useful Knowledge;” and hath at length brought it to great Forwardness, so as to be fit for putting to the Press; and whereas he hath been at great Labour, Pains, and Expencc, in prosecuting the said Work, which he humbly presumes will be of Service to Our Subjects concerned in *Arts, Trades* and *Manufactures*, as tending to promote that Kind of Knowledge on which they depend; He therefore most humbly prays Us to grant him Our Royal Licence and Privilege for the sole Printing, Publishing, and Vending the said Work, for the Term of Fourteen Years, agreeable to the Statute in that Case made and provided: We are graciously pleased to condescend to his Request, and do accordingly, by these Presents, as far as may be agreeable to the Statute in that Case made and provided, grant unto him the said WILLIAM LEWIS, his Executors, Administrators, and Assigns, Our Royal Licence for the sole Printing, Publishing, and Vending the said Work, for the Term of Fourteen Years from the Date hereof; strictly forbidding all our Subjects, within Our Kingdoms and Dominions, to Reprint, Abridge, or Publish the same, either in the like, or any other Volume, or Volumes, whatsoever, or to Import, Buy, Vend, Utter, or Distribute any Copies thereof Reprinted beyond the Seas, during the aforesaid Term of Fourteen Years, without the Consent and Approbation of the said WILLIAM LEWIS, his Heirs, Executors, Administrators, and Assigns, under their Hands and Seals, first had and obtained, as they will answer the contrary at their Peril; whereof the Commissioners, and other Officers of Our Customs, the Master, Wardens, and Company of Stationers, are to take Notice, and that the same may be entered in the Register of the said Company, and that due Obedience be rendered to Our Will and Pleasure herein declared.

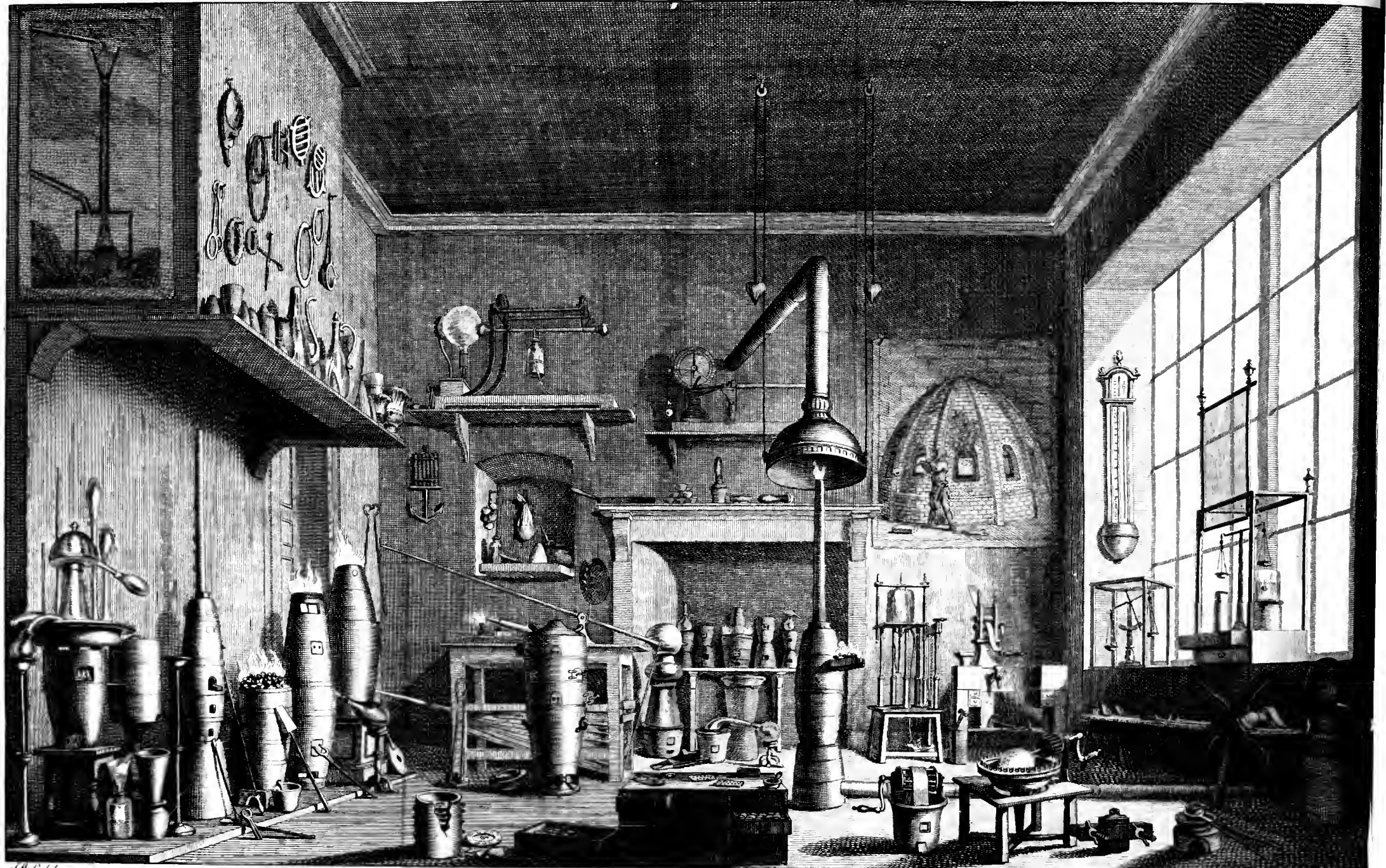
Given at Our Court at *St. James's*, the Eighth Day of *February*, 1762, in the Second Year of Our Reign,

*By His Majesty's Command.*

E G R E M O N T.







*A. Wall del.*

*P. C. Lanot sc.*

C O M M E R C I U M

*Philosophico-Technicum;*

OR, THE

PHILOSOPHICAL COMMERCE

O F

A R T S :

DESIGNED AS

AN ATTEMPT TO IMPROVE

Arts, Trades, *and* Manufactures.

---

By *W. LEWIS*, M. B. and F. R. S.

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*Fiat Experimentum.*      BACON.

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L O N D O N,

Printed by H. BALDWIN, for the AUTHOR;

And Sold by R. WILLOCK, at Sir Isaac Newton's Head in Cornhill.

MDCCLXIII.



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LON.



TO THE  
K I N G.

S I R,

**T**HE advancement of arts, trades, and manufactures, and the extension of commerce, are now become the more immediate objects of Your Royal care ; as being the most certain means of attaining Your darling wishes, the rendering Your people powerful and happy, and perpetuating the blessings of peace. I have therefore presumed, with all humility, to offer to Your MAJESTY'S protection, a work designed to improve and enlarge many of the arts of peace, and to promote that kind of knowledge on which they depend. The importance of the subject, and the honour, the never to be forgotten honour, which

Your

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YOUR MAJESTY was pleased to do me, by Your attention to some lectures and experiments, made by Your command at Kew, for shewing the application of chemistry to the improvement of practical arts as well as of philosophy, will, I hope, excuse this ambition in

YOUR MAJESTY'S

Most humble and devoted

Subject and Servant,

Kingston on Thames,  
7th of April, 1763.

William Lewis.

THE  
PHILOSOPHICAL COMMERCE  
OF  
ARTS :

DESIGNED AS  
AN ATTEMPT TO IMPROVE  
*Arts, Trades, and Manufactures.*

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By *W. LEWIS*, M. B. and F. R. S.

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*Fiat Experimentum.*      BACON.

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L O N D O N,

PRINTED for the A U T H O R;  
And Sold by R. W I L L O C K, at Sir Isaac Newton's Head in Cornhill.  
M.DCC.LXV.





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# P R E F A C E.

**A**S all the arts, by which matter is diversly modified and accommodated to human uses, have a necessary dependence upon the properties or qualities of the bodies on which they are exercised; enquiries into the properties of different bodies, and the effects resulting from various applications of them to one another, become apparently of primary importance, as well for the illustration and improvement of the present arts and the discovery of new ones, as for the advancement of useful knowledge.

THE properties of bodies make the object of two sciences, *natural philosophy* and *chemistry*; which, though in many cases so closely interwoven, and so nearly allied, that perhaps no boundaries can be established between them, appear in others to have essential and important differences. In the introduction to a work, of which enquiries into the properties and relations of bodies make a principal part, the necessary precision, in regard to matters of fact, as well as of science, requires that we should endeavour to distinguish them.

NATURAL or mechanical philosophy seems to consider bodies chiefly as being entire aggregates or masses; as being divisible into parts, each of the same general properties with the whole; as being of certain magnitudes or figures, known or investigable; gravitating, moving, resisting, &c. with determinate forces, subject to mechanic laws, and reducible to mathematical calculation.

CHEMISTRY considers bodies as being composed of such a particular species of matter; dissoluble, liquefiable, vitrescible, combustible, fermentable, &c. impregnated with colour, smell, taste, &c. or consisting of dissimilar parts, which may be separated from one another, or transferred into other bodies. The properties of this kind are not subject to any known mechanism, and seem to be governed by laws of another order.

To the grand active power, called *attraction*, in the mechanical philosophy, what corresponds in the chemical is generally distinguished by another name, *affinity*.

The mechanical attraction obtains between bodies considered each as one whole, and between bodies of the same as well as of different kinds. It obtains while the bodies are at sensible distances; and the comparative forces, with which they tend together at different distances, are objects of calculation. When the attracting bodies have come into the closest contact we can conceive, they still continue two distinct bodies, cohering only superficially, and separable by a determinate mechanic force.

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The chemical attraction, or affinity, obtains between bodies as being composed of parts, and as being of a different species of matter from one another. It never takes place while the two bodies are at any sensible distance; and when they are brought into the closest contact, there is frequently necessary some other power, as fire, to excite their action upon one another. In proportion as this action happens, they are no longer two bodies, but one; the affinity consisting in the intimate coalition of the parts of one body with those of the other. The properties of this new compound are not in any kind of ratio of those of the compounding bodies, nor discoverable by any mathematical investigation: two bodies, each by itself very easily fusible in the fire, as lead and sulphur, shall form a compound very difficult of fusion; and two which cannot separately be made to melt at all, as pure clay and chalk, shall melt with ease when joined together.

As the chemical union, and the properties thence resulting, are exempt from all known mechanism, so neither can the bodies be separated again by mechanic force. But a third body may have a stronger affinity to either of the component matters than they have to one another, in which case, on presenting to the compound this third body, the former union is broken, and one of the first bodies coalesces with the third, while the other is detached and separated.

Thus, when quicklime is dissolved in water, if we add to the transparent fluid a little vitriolic acid, the acid particles unite with the dissolved particles of the lime into a

new compound; which, notwithstanding the pungent taste of the one ingredient, the corrosive acidity of the other, and the solubility of both, proves insipid and indissoluble, and which therefore, separating from the water, renders it at first milky, and on standing settles to the bottom, in form of powder or small crystals, of the same general properties with the native gypsums or plaster-of-paris stones.

If this powder be ground with inflammable matter, as powdered charcoal, no action happens between them, how exquisitely soever they be mixed: the two powders continue gypsum and charcoal, and may be in great measure parted from one another by means of water, the charcoal powder remaining for a time suspended in the fluid, while the heavier gypsum settles. On exposing the mixture to a proper degree of heat, a strong chemical affinity begins to take place: the acid quits the lime, and unites with the inflammable principle of the coal, forming therewith another new compound, common brimstone, which, like the former, proves insipid, and indissoluble in watery liquors, though in other properties remarkably different; melting in a small degree of heat into a red fluid; in a somewhat greater heat, if air is excluded, rising into the upper part of the vessel unaltered; on the admission of air changing into a blue flame, with a suffocating volatile acid fume, which by air and moisture returns into the original, inodorous, ponderous, vitriolic acid.

By mixing the brimstone with iron filings, a fresh transposition is produced; and as in the preceding case the action is excited by fire, so in this it is excited by water. The mixture,

mixture, kept perfectly dry, continues unaltered for years : on being moistened with water, it grows spontaneously hot in a few hours, and if the quantity is large, it even bursts into flame, with such commotion, as has induced many to ascribe earthquakes and volcanoes to this cause. During this action, the acid is transferred to the iron ; and the inflammable matter, before combined with it, escapes into the air. The combination of the acid with the iron forms the green vitriol or copperas of the shops ; a salt of a strong taste, and of easy solution in water, though the quantity of iron in it is very far greater than that of the inflammable matter by which, in the form of brimstone, the miscibility of the acid with water was destroyed.

To the green solution of the vitriol, if some vegetable ashes, or the earth called magnesia, be added, the iron falls to the bottom, considerably altered, in form of ochre or rust, deprived of its attractive power to the magnet, and of all its metallic properties, which however are easily restored by exposing it to the fire in mixture with a little charcoal powder. In room of the iron thus thrown out from the liquor, the acid attacks the vegetable earth or magnesia ; and though with one kind of earth, as we have seen above, it forms an insipid and indissoluble concrete ; with both these earths it composes a bitterish salt which dissolves easily, and which, at least when magnesia is made use of, is the same with that of the purging mineral waters.

If to the solution of this salt we add a volatile alkaline salt, the penetrating smell of the alkali is suppressed in an instant, the acid uniting with the alkali into a new compound,

pound, and depositing the earth which it had taken up before.

From this compound, fixt alkaline salts absorb the acid, and set at liberty the volatile alkali with all its original properties. Though the acid and fixt alkali, separately, are very pungent and corrosive, and so strongly disposed to unite with water that they imbibe it from the air, yet the combination of the two has only a mild bitterish taste, and dissolves in water very difficultly and sparingly.

After all these transpositions, the acid may still be recovered pure, and made to pass again through the same and through a multiplicity of other combinations. From almost all its combinations it may be transferred to inflammable matter, and from the inflammable matter to iron: from the brimstone, which it forms with the one, the acid may be obtained by burning with a proper apparatus; and from the vitriol, which it forms with the other, by distillation.

IT is obvious, that in all these cases, the action is not between bodies considered as aggregates or masses, but between the insensible and dissimilar parts of which they are composed; that the several effects can be regarded no otherwise than as simple facts, not reducible to any known mechanism, not investigable from any principles, and each discoverable by observation only; and that the powers, on which they depend, are, so far as can be judged in the present state of knowledge, of a different kind from those, by which bodies tend to approach or cohere with forces proportionate to their distances, or to resist or propel according

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ing to their quantities of matter and velocities. It seems of importance, that these two orders of the affections of bodies be kept distinct, as many errors have arisen from applying to one such laws as obtain only in the other.

WHEN Archimedes observed, in the bath, that the bulk of a body, however irregular, might be found, by plunging it into a vessel of water, and measuring the water which run over, or the space which the water occupied in the vessel more than it did before; and that gold has near twice the weight of silver under an equal bulk; he concluded, that if gold and silver were mixed together, the quantity of each metal in the mixture might be found by calculation from the bulk of the mass compared with its weight; and on this foundation, he is said to have discovered a fraudulent addition of silver made by the workman in Hieros golden crown, at a time when the chemical methods of analysing and assaying metallic compositions appear to have been unknown.

The mechanical philosophy has extended this way of investigation to many different mixtures, and computed tables for facilitating the operation; not aware, that though the method is demonstrably just if the two bodies were joined only superficially, the case is otherwise when they are intimately combined together. The act of combination, whether in bodies brought into fusion by fire, or in such as are naturally fluid, is truly chemical, and the laws of the mechanical philosophy have no place in it. There are instances, some of which will appear in the present volume, of bodies being dilated on mixture into a larger

larger bulk than they had before; and, contrariwise, of two being contracted into less bulk than even one of them occupied by itself.

To render the process anywise to be depended on, actual mixtures of the respective bodies ought first to be made, in different proportions, and examined hydrostatically, that the quantity of contraction or dilatation in particular cases may be known and allowed for. By thus borrowing from both sciences, we are furnished with means of discovering the proportions of the ingredients in many mixtures, provided the ingredients themselves are known, with tolerable certainty: in some mixtures, as of lead and tin, this method is more commodious, and perhaps more exact, than any which pure chemistry has afforded.

IN this manner the mechanical and chemical sciences concur, and require the assistance of one another, in their own operations, and in almost all the manual arts. In the greater number of the arts the chemical prevails, and many are no other than direct branches of practical chemistry, as the arts of dying and staining, the running down of ores, the refining and compounding of metals, the making and colouring of glass, enamel, porcelain, &c. making wines, vinegars, spirits, &c. preparing indigo, smalt, Prussian blue, vermilion, lakes, and other colours for the painter. It is in those arts, and in those branches of arts, which are strictly chemical, that the most important and most numerous discoveries are to be expected: chemistry having hitherto been the least cultivated, though  
not



not the least fruitful; and producing daily, not barely new applications of principles already known, but new facts or principles to be further applied.

HAVING for several years employed myself at times in experiments relative chiefly to the chemical arts, and made proper dispositions for continuing such enquiries, I published in 1748 proposals for a very extensive work, consisting principally of those experiments, and of informations received from workmen and others. The several articles were to be printed in a miscellaneous manner, without regard to any one being connected with that which preceded or followed it. As nothing was to be admitted but useful or interesting facts, it seemed of little importance in what order the facts should be disposed, provided, by means of proper indexes, the reader could readily have recourse to such particulars as might occasionally be wanted.

Some friends advised an alteration in this plan, judging it would be of more utility to the publick if the facts were methodized; and the most convenient method was thought to be, to give a complete history of each art by itself in all its branches. The difficulty of such an attempt, and the impossibility of executing it to any good purpose by one hand, were apparent: nor would a simple detail of the manual operations of different workmen be anywise agreeable, either to the views, or the materials, with which I had engaged in the undertaking.

ANOTHER way occurred of procuring some degree of regularity, without departing from the original views, any otherwise than by rendering them more comprehensive.

Many of the arts have natural and strong connections with one another; working upon the same materials, for purposes either different or nearly the same; or producing similar effects upon different or similar subjects. One property of such materials, or the production of one effect, may therefore influence several arts: a colour, which can be easily fixed in animal and vegetable fibres, is equally of benefit to the woollen dyer, the silk dyer, the dyer of linen and cotton thread, and the callico printer: a colour which will bear fire, and unite with vitreous bodies in fusion, concerns equally the glass maker, the enameller, and the painter on porcelain.

The discoveries and improvements made in one art, and even its common processes, are generally little known to those who are employed in another, so that the workman can seldom avail himself of the advantages which he might receive from the correlative arts, and an effect wanting to the perfection of his own art may be actually produced in another. Thus, though the dyer of linen cloth, and of linen and cotton thread, wants means of communicating to them a black dye that shall endure wearing, the callico printer fixes both on linen and on cotton a black as durable as can be wished for.

To enquire therefore by experiment into the different means of producing one effect, and trace it through all the arts in which such an effect is required; to examine the chemical properties of one subject-matter, and consider its uses and applications in all the arts in which it is concerned; to proceed in this manner with the capital effects, and materials, so far as my own experiments, and my opportunities.

portunities of information, should enable me; appeared to be the most rational and direct means, not only of establishing solid principles of the several arts as now exercised, but of procuring an useful intercourse and communication of knowledge, of supplying many of their defects, of multiplying their resources, of improving their products, of facilitating and simplifying some complex operations, and rejecting useless ingredients in sundry compositions, of enriching one art with the practices, materials, and sometimes even with the refuse-matters of another.

SUCH therefore is the plan which I have chosen to follow, and of this alteration I gave notice in an advertisement in 1761.

I have the satisfaction to find that the French academy of sciences, who, with the advantage of pensions from the sovereign, and with the assistance of experienced artists in different professions, have been engaged for near a century in a history of arts which has but lately been begun to be published, express exactly the same sentiments with those on which I have proceeded. In the memoirs for 1763, the historian of the academy, in giving notice of the publication of that work, observes that "an inconvenience to be feared is, the want of that knowledge, and of those general principles, which bind arts as it were together, and establish between them a reciprocal communication of light. All the arts, for example, that employ iron, have common principles, but it would be in vain to expect the knowledge thereof from those who exercise these arts,

each of whom knows only the application of those principles to his own art. The farrier, the locksmith, the cutler, know how to work iron; but each of them knows only the manner of working which he has learnt, and is perfectly ignorant that the art of working iron has general principles, which would be infinitely useful to him in a great number of unforeseen cases, to which his common practice cannot be applied.---'Tis only by bringing the arts as it were to approach to one another, that we can make advances towards their perfection: we shall thus put them in a condition of mutually illustrating one another, and perhaps of producing a great number of useful discoveries: 'tis only by this means that we can know effectually their true principles, and enable them to receive assistance from theory."

It were to be wished, that convenience had permitted these reflections to have had their full influence in the execution of the work. The history is published in detached and independent pieces, each containing a minute detail of the whole series of operations of one art, with descriptions and plates of all the instruments made use of: it is designed not only to supply the philosopher with the knowledge otherwise obtainable only among workmen, and to entertain the mind with the history of human inventions, but likewise to enable persons to exercise the respective trades in places where workmen are wanting.

It is obvious that this plan does not at all interfere with mine, and that the views of the two undertakings are essentially different. It is not my design to dwell upon descriptions of common and merely manual practices, to give particular

particular instructions for the setting up and conducting of common manufactures, or histories of establishments which must vary with times and circumstances. The articles which make the main objects of my enquiries are founded on the invariable properties of matter; and besides the consideration of arts in their present state, experiments for improving them, or researches in that branch of knowledge from which their more valuable improvements must arise, make a principal part of the work.

WITH the advantages that result from the abovementioned alteration in the plan, the execution becomes far more difficult. What is fact or otherwise in regard to the properties of bodies, or the effects resulting from different operations on them, is to be determined by experiment. In the miscellaneous method, we have no occasion to enter upon any points where the determination of experiment has not been clearly obtained. But in a regular history the case is otherwise: we shall often be led into subjects with which we are not sufficiently acquainted, and though we thought we had materials in abundance, we shall find some deficiency, greater or less, in almost every page: there are numerous particulars, which are not missed in the detached fragments of knowledge, but whose want is striking when these fragments come to be joined and methodised into one whole. From this cause, and from the difficulty and tediousness, in some cases, of obtaining the necessary informations among different workmen, unexpected delays, if we aim at making the history tolerably complete, must frequently happen in the publication; nor will it be easy,

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on certain occasions, even to avoid errors: indeed in direct experimental enquiries, the effect of the operation is sometimes so much influenced by circumstances which are apt to pass unheeded, that it is not to be wondered if errors are to be found in the writings even of the most accurate experimental chemists.

THE history of each subject I have made as complete, as my present means of information, and the experiments I have hitherto made, will permit; but much remains still undetermined and unexamined: if the work goes on, and the author should be able to execute it to the utmost of his hopes, the publick is not to expect that any article will be perfect: researches in chemical knowledge we can never hope to make complete, every new acquisition shewing new paths for our further progress in a province of unbounded extent. Such material deficiencies as occurred upon a review of the volume, and some mistakes which I had been led into either by my own inadvertence or the authority of others, are taken notice of in the appendix. It is hoped that the same regard for the publick; which influences the author, will prevail on those who may discover any other mistakes of moment, to give him an account of them, that they may be rectified in some future publication. It is hoped also, that from the communication of friends and artists, much of what is wanting in one publication may be supplied in the next.

ONE of the principal obstacles to the prosecution of chemical enquiries has hitherto been the want of a proper apparatus.

apparatus. I have therefore begun the work with an attempt to remove this impediment; to procure, at a small expence, a commodious and easily manageable set of furnaces, &c. which may be all worked under a common chimney, and some in the middle of a room without offence, and with which most of the operations, that require the assistance of fire, may be performed, in the way of experiment, with great ease, expedition, and safety: if those, who have been accustomed to the common larger and more expensive furnaces, should at first be at any loss in the use of these small ones, a very little practice and attention will remove all difficulties, and convince the operator of the convenience which I have long found from them in experimental pursuits, for which alone they are designed. The structure and management of the large furnaces, kilns, &c. used in different businesses, are intended also to make part of this work, and mechanical contrivances of other kinds are likewise occasionally considered, with a view chiefly to render them more simple, convenient, or effectual. In the present volume I have given an entire essay on the improvement of the machines for blowing air into large furnaces, &c. by a fall of water, without moveable bellows, in virtue of the water carrying down air with it in falling through pipes; and I have the pleasure of being informed, by a foreign correspondent, of a machine which he has constructed on the principles there established, which answers as well as can be desired.

It would be needless to specify in this place the several matters contained in the volume: a list of them may be seen.

seen in the table of contents. It is sufficient here to have explained the principles, and the views, with which the author has engaged in the work. How far these principles and these views have a just foundation, or may tend to the advancement of arts and useful knowledge, and whether this laborious and expensive undertaking shall be dropt or prosecuted, is left to the determination of the publick.



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C O M-

## E R R A T A.

*Page 89, line 10, 11. for two parts of tin and three of gold, read two parts of gold and three of tin.*

*Page 556, line 10 from the bottom, for 87 parts read 97 parts.*

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# C O M M E R C I U M

## PHILOSOPHICO-TECHNICUM.

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### *I. Description of a Portable Furnace for making experiments.*

**P**ORTABLE furnaces have been generally contrived, not only with a view to the purposes of experiment, but likewise for answering in some degree the demands of business. As the size, which procures them this last advantage, renders them less fit for the first and principal intention; I have long endeavoured to contrive a more manageable, as well as less expensive furnace, for experimental enquiries; and to bring these kinds of instruments as near as may be, in regard to the facility and the conveniency of their use, to the same footing with the air-pump, the condensing engine, and other like instruments employed in philosophical researches.

The first hint of the apparatus here described was taken from the practice of an ingenious workman in gold; who employed occasionally, as a melting furnace, two of the larger kind of black lead pots, or blue pots as they are sometimes called, one inverted over the other. Four or five small iron bars, passed across the under-

B

most

most pot, in its lower part, through opposite holes made for that purpose, served for a grate: the fuel, and the crucible containing the metal, were put in at the mouth of the pot: a hole in the side, made under the grate, admitted air to the fuel: and the upper inverted pot, having a hole cut in its top, supplied the place both of a dome and chimney. By this means he could melt, with ease and expedition, several ounces of gold at a time; and conveniently examine the metal, during the fusion, by raising or lifting off the upper pot.

A judicious variation of this simple contrivance promised to afford furnaces of more extensive utility. Black lead pots appeared peculiarly well fitted for this use; common experience having shewn, that they bear vehement fires without melting, repeated or continued fires without being so liable to fail as any of the other kinds of crucibles, and quick vicissitudes of heat and cold without being so liable to crack: on these properties their excellence as crucibles depends. They have another quality, inessential to them as crucibles, but which particularly adapts them to the making of furnaces: they admit freely of being ground, drilled, sawed with a common toothed saw, and cut with any kind of edged or pointed tool; so that the necessary doors, groovings, &c. may be readily made in them with common instruments, and stoppers for the doors formed out of broken pieces.

Having seen two of these crucibles form a convenient melting furnace where only a moderate fire was required: it was plain that a stronger fire might be excited in them by the means used for that purpose in other furnaces, *viz.* a bellows or a chimney; that one crucible would serve as a furnace for those uses in which no dome is wanted; and that if the upper crucible was fitted up in the same manner as the lower, it would in such case be a distinct furnace of itself. It remained therefore to determine

mine the most proper construction of the two crucibles, for adapting them to different purposes, separately or combined.

THE black lead crucibles of that size, which has the number 60 marked on the bottom, I have found to be the best suited for the general uses of furnaces: their perpendicular height, in the inside, is about twelve inches; their width at the mouth somewhat less than eight inches, and about the middle of their height six and a half. These vessels I have fitted up in different methods, and found the following construction to be in general the most commodious.

Each crucible has its mouth ground smooth and flat, upon a stone, with a little sand; and a round hole sawed in its bottom with the common compass saw of the carpenters. In the side, a little above the bottom, another round hole is made; and opposite to this, a square one; above which is cut a larger square one. The places of these apertures, and their comparative sizes, are represented in the annexed plates; in which all the figures are drawn to one scale, to prevent the necessity of embarrassing the description with an account of the particular dimensions of the several parts.

All the apertures are fitted with stoppers, cut out of pieces of broken crucibles, which are easily procurable at those places where the pots themselves are sold. The square apertures are made, at each of their sides, a little narrower internally than externally, by which means the stoppers, though their surface lies equal with that of the outside of the pot, are prevented from being pushed inwards: this slope is made on the sides, and not on the top or bottom, that the stoppers may not be liable to fall out when the pot stands on either end. The round ones are in little danger of falling out, being made to fit close, by

grinding them into the apertures. The stoppers are conveniently taken out and put in by means of a kind of fork, each stopper being furnished with two small holes for introducing the points: these holes are made at the same distance from one another, in all the stoppers of both the crucibles, so that the same instrument serves for them all: a springiness in its legs accommodates it to small inequalities. The bottom stopper is better managed by the hand or tongs; a circular cavity being cut in it, so as to leave a knob for that purpose in the middle.

The grate consists of an iron ring, with cross bars fixed in it: the thickness or depth of the bars is considerably greater than their width, that they may have sufficient strength, and that the spaces between them may be as great as possible: the ring is formed of a bar, of the same dimensions, turned round. Three of these grates, of different widths, are required for different uses: one, of such a size, that it may rest against the converging sides of the pot, in the lower narrow part, just above the lowermost square hole; another, so large that it may enter no further than nearly to the top of the uppermost hole; and the third, of the same width with the outside of the mouth of the crucible. One grate of the smaller size is necessary for each of the furnaces; but one of each of the other two sizes is sufficient for both furnaces; those operations which require either of these grates, requiring at the same time both the pots. For more effectually keeping the lower and middle grates in their places, either grooves are cut for their edges to rest upon, all round the pot; or three notches are made, for each, at equal distances, in the pot, and corresponding knobs or pins on the circumference of the grate; which pins are rivetted into the ring. This last method is the most eligible,

eligible, as it admits of most interstices for the air to pass through, and the ashes to fall down; for here, as great a space may be left between the rim of the grate and the sides of the pot, as between the bars; and this vacuity round the sides is the more useful, as the ashes are there most liable to be accumulated, and the fire to be languid. In whatever manner the grate is supported, care must be taken that it have sufficient freedom, and that neither the grate itself, nor its knobs, bear hard against the sides; lest the expansion of the metal, when heated, should not only make the grate difficult to be got out, but likewise damage the furnace.

To render the furnaces sufficiently durable, they are bound round, in three or four different parts, with copper wire, so as not to interfere with the doors or holes. The wire is about the size of a crow quill, or somewhat larger, and is softened and made pliable by nealing or heating it on live coals: it is prevented from slipping by a slight groove made for it round the furnace; and its ends are drawn together, and twisted tight, with pincers. The mouth is most effectually secured by a thin copper hoop, which prevents the edges from being broken or worn off: the flexibility of the thin copper admits of its accommodating itself to the figure of the furnace; and what small space remains between the furnace and its upper edge, is filled with a little moist loam, or with clay mixed with some powdered pots. The crucibles thus armed, continue serviceable, after they have been so much cracked that they would otherwise fall in pieces.

These furnaces are conveniently lifted or carried by means of a moveable handle, made of an iron rod, or a piece of strong iron wire, about three feet long, bent, like the bale of a pail, to the width of the furnace,  
with

with the two ends turned inwards, so as to enter into two small opposite holes made in the furnace, through the copper hoop: the springiness of the iron rod admits of the extremities being easily drawn asunder sufficiently for the introducing or withdrawing of the hooks.

BESIDES the black lead crucibles which make the body of the furnace, there are required, a foot for them to stand upon, a chimney, and an iron hoop.

The best sort of foot is a flat, heavy, iron ring, with three legs five or six inches high: in one of the legs of this trevet is a screw, by which it may be occasionally raised or lowered, so that the furnace is made to stand level though the floor be uneven. A foot may be formed also of the lower part of another black lead crucible inverted; by making a suitable aperture in the bottom, and sawing three arches, at equal distances, in the sides, so as to leave between them legs of sufficient strength. One of the furnaces, inverted, makes likewise a convenient foot for the other. Where either of these feet is used, the ashes, that fall down, are received in an iron pan, such as a frying pan with the handle cut off, placed underneath. If the furnace is set on a stone, an iron plate, or any other solid support, the ashes, accumulated in long operations, are raked out at the lower aperture in the side, by means of a piece of narrow iron plate conveniently bent at one end.

The chimney is composed of three pipes of forged iron plate, which should not be thinner than one eighth of an inch, that they may not soon be bent or destroyed by the fire. Each pipe is a foot and a half or two feet long. The undermost, that it may stand steady, has a broad heavy ring round it, about an inch above the lower



end, which lower part enters into the hole in the top of the inverted pot: the upper end of the pipe is received into the lower end of the next, and the end of this is in like manner received by the third; so that the chimney is nearly of the same width, or only insensibly converging from the bottom to the top. It is convenient to have the upper end made square, that it may fit into the larger door of the furnace, and thus serve occasionally as a lateral chimney.

The hoop is formed of a forged iron plate, not less than one sixth of an inch thick, turned round, and welded together at the ends. It is about six inches deep; and of the same width externally with the top of the furnaces, but its thickness being less than that of the furnaces, it is internally wider. One end of this hollow cylinder has an iron ring passing round it within: this is the end on which it most commonly stands, upon the mouth of one of the pots; and the ring contributes to make it stand steady, as well as to strengthen it. Near to this end is a semicircular aperture whose door is rivetted on a large iron plate, which opens downwards on hinges, and drops no lower than to an horizontal situation. There is no occasion for the hoop being luted; for if made of good hammered iron, of the thickness above directed, it will be sufficiently durable, without any defence, in the greatest degrees of heat which it is intended to support.

ONE of the black lead crucibles, prepared as above described, with the lower small grate introduced into it, is a furnace for open fire: the lower square aperture, immediately under the grate, is the door of the ash-pit; and the upper one, above the grate, is a door to the fire-place: which last, in the intentions this furnace is designed for, is kept shut. The fuel, which must in all cases

cases be charcoal, and of which the consumption is in these kinds of furnaces inconsiderable, is put in at the top, and is supplied with air through all or any of the apertures beneath the grate: by more or less closing or opening these apertures, the fire is diminished or increased.

This open furnace, besides its use for keeping fuel ready lighted to be employed in others, affords the conveniency of nealing metals when grown hard or rigid by hammering or rolling; of setting any small vessel occasionally upon the coals, as a crucible or iron ladle for the melting of the more fusible metals, and serves for many other like purposes that occur in practice.

By introducing into the open furnace an iron pot, empty or containing sand; it becomes a furnace for a *capella vacua* as it is called, or a sand furnace; in which the only variation from the preceding is, that the mouth of the furnace being occupied by the iron pot, the fuel is put in through the fire-place door or the aperture above the grate.

An iron ladle, with its handle cut short, serves extremely well for the *capella* or sand pot. It is supported over the fire by means of a flat iron ring, into which the ladle is inserted so as to bear against the ring by its upper wide part. It is necessary to have several of these rings, of different internal diameters for receiving ladles and other vessels of different sizes, but all of them wide enough externally to rest upon the top of the furnace. Between the furnace and the ring are inserted, at equal distances, three iron supporters, about a quarter of an inch thick, an inch long, and equal in breadth to the thickness of the sides of the furnace. Through the space thus procured beneath the ring, the burnt air passes off; and being permitted to issue freely on all sides, the heat is distributed,  
and

and the vessel heated all round : whereas, in those furnaces, where the air passes off by an elbow or chimney at one side, the action of the fire is chiefly upon one side of the vessel, and consequently, besides an inequality of the heat, a greater quantity of fuel becomes necessary for producing in the vessel the same degree of heat. The admission of the air by the bottom hole, perpendicularly under the grate, has likewise some advantage in this respect above the lateral admission of it by the door.

INSTEAD of the foregoing kinds of vessels, narrower than the furnace so as to be received into it, a much broader one may be placed upon the top, with the three iron supporters under it to procure a space for the passage of the air. The flat iron pan, which on other occasions is set underneath the furnace for receiving the ashes, may be used in this manner as a vessel for calcinations, for the evaporation of solutions of lixivial salts, &c.

FOR vessels of a deeper kind, as a copper still, the capacity of the furnace is increased by placing over it the iron hoop; by which it is enabled to receive the body of a still, of a size sufficient for the purposes of an experimental laboratory. In other respects, there is no variation from the preceding form : the fuel is put in through the door above the grate; and the still or other vessel hangs, like the capella or sand-pot, in an iron ring, which rests upon the three iron supporters placed upon the hoop.

With regard to the distilling vessels, their structure differs from that of the large ones in common use. The body of the still is a wide copper pan; and, for distillation in a water bath, another vessel of the same figure is received into it almost to the top, as represented in the first plate, the space between them being nearly filled with water. Both

these vessels are of the same width at the mouth, so that the same breast fits them both, and either may be used as a still equally with the other : either of them serves also, on other occasions, as an evaporating pan, a boiler, for experiments in dying, and other like purposes. All the parts are made of thin copper plate, and well tinned on the inside with pure tin : in consequence of their thinness, they admit of some alteration of their figure about the edges, so that, though they should not be perfectly round, they are readily accommodated to one another, and fit close : the juncture is easily made perfectly tight by applying round it narrow slips of moistened bladder ; which are more convenient than luting, as being readily stript off when the operation is finished. A short pewter pipe, with a pewter stopper fitted to it, for returning the distilled liquor, or pouring fresh liquor occasionally into the still, without the trouble of unluting and separating the vessels, is soldered into the top of the head ; which, in these kinds of instruments, is the most convenient place for it. For separating, by distillation, spirituous from watery liquors, or the rectification of spirit of wine, the head is raised, by inserting, between it and the breast, a thin copper pipe about two feet long. A worm and refrigeratory are necessary, as for the common still : and a glass head is requisite for some uses, particularly for the distillation of vinegar, and such other liquors, as would corrode a copper one, and impregnate themselves with the metal ; in which case, the use of the metalline worm also is to be avoided, and the glass or stone-ware receiver joined to the pipe of the head.

The above apparatus is as commodious, as can be wished, for distillation in the way of experiment. Contrivances for expediting and accelerating the process do not belong to the present design : but as this is an affair  
of

of great importance in fundry cafes, particularly for procuring fresh water eafily at fea, I was engaged by the late Dr. Hales, whose extenfive philanthropy will ever render him dear to mankind, and who had this falutary object greatly at heart, to undertake a fet of experiments directly with this view ; the refult of which fhall be communicated in a feparate article of fome of our future publications.

A WIND-FURNACE, for the fufion of metals, the affaying of ores, and other like ufes, is formed by inverting one pot over the other ; and placing on the top either the entire chimney, or two or one of its pipes, according as the fire is wanted to be more or lefs ftrong. The fecond grate, in the middle of the undermoft pot, is generally, in thefe intentions, more proper than the lower fmall one made ufe of in the former cafes, on account of its having more interftices for admitting air to the fuel. The crucible, containing the fubject-matters, is placed upon a circular flip of brick, or of a broken pot, a little wider than its bottom, laid upon the middle of the grate, to prevent the cold air from ftriking on it. The charcoal is put in through the fire-place door, or larger aperture, of the dome or upper pot, which fhould always be clofed after each fupply of fuel. The furnace ftands on its trevet or open foot ; with the flat iron pan underneath, not only for receiving the afhes, but that, if the crucible fhould happen to fail during the fufion, its fluid contents may be preferved. The two oppofite holes in the upper part of the dome afford the conveniency of paffing an iron rod through, for fafely and commodioufly lifting it when intenfely heated.

THE round hole in the sides of these furnaces gives an opportunity of introducing the nose of a pair of double bellows; so that one pot singly, or two combined together as in the foregoing article, may be readily converted into a blast furnace; in which case all the other apertures beneath the grate must be closed while the bellows acts, to prevent the air forced in by it from escaping. It is of great advantage, in sundry operations, to be thus able, at certain periods, to suddenly animate the fire.

ONE pot inverted over the other, with the iron hoop placed between them, make a furnace for cupellation, calcination under a muffle, and the other purposes of what is called the assay furnace; as also for experiments of enamelling, of baking colours on earthen ware and glafs, &c. The chimney, or a part of it, is occasionally set upon the top for raising the fire when it proves too languid.

In want of the muffle made for operations in the assay furnace, its office may be supplied by a common crucible laid upon its side, with a bed of loam in it to form a flat surface for the cupels or other vessels to stand on. The largest of the three grates is set upon the lower pot, which it wholly covers; and the iron hoop, which of course bears upon the rim of the grate, is placed with its door lowermost. The muffle, or its substitute, is laid upon a slip of brick on the grate, with its mouth fronting the opening in the hoop, through which the cupels, &c. are introduced. In processes which require frequent inspection of the subject-matters, and the admission of heated air; the plate, on which the door of this aperture is rivetted, is let down to an horizontal situation, and some pieces of lighted charcoal, with sufficient interstices between them for the cavity of the muffle to be seen, are laid upon the  
plate,

plate, which, for this purpose, is made about two inches wider than the door, and as long as the height of the hoop will admit it to be. The fuel is put in, as before, through the fire-place door of the dome. As the part of the furnace above the grate widens downwards, the coals generally of themselves fall properly round the muffle: if this should not happen, they are easily pushed down by means of a crooked iron wire introduced through the door. The dome is lifted off, as in the wind-furnace, by an iron rod passed through its opposite apertures.

THE foregoing combination, of the two pots and the iron hoop, with or without the chimney or a part of it according as a greater or less degree of heat is required, serves also as a reverberatory, for distillation in coated glass retorts, earthen retorts, or longnecks; with only this variation in their disposition, that instead of the large grate, the middle one is introduced into the undermost pot, and in its upper part two iron bars are laid across: the bottom of the distilling vessel rests upon these bars, and its neck comes out at the door of the hoop, which is accommodated to vessels of greater or less height by placing it with the door uppermost or lowermost. Both the reverberatory and the assay furnace are, in effect, no other than the wind-furnace; with a muffle or a retort set in the fire instead of a crucible.

THESE furnaces may be used likewise as a common stove, for keeping a room warm with a little quantity of fuel. There are three general intentions which have been pursued in contrivances for this purpose; (1) making the fuel take fire by degrees, and consume slowly; (2) conducting its heat, or the air warmed by it, through a number of passages or circumvolutions, that the heat,  
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instead of being carried up the chimney, and thus lost, may be detained in these passages, and thence communicated to the air of the room to which they lie exposed ; and (3) applying to the fire a quantity of solid matter, which, being once heated, preserves its heat long. Some ingenious furnaces, on these principles, are described in the Transactions of the Swedish Academy, and in the second edition of Reaumur's Art of hatching Birds. All these contrivances are united in the following combination of the two pots and the hoop.

The undermost pot has the small grate introduced into its lower part, the fire-place door closed, and the ash-pit door or the bottom hole open for admitting air. Being then charged with small pieces of charcoal, and some lighted coals thrown above them, its top is covered by the largest of the grates, and on this is placed the hoop and dome, filled with balls of baked earth, or with pieces of bricks, so disposed as to leave small vacuities between them. If the stove is placed in the middle of a room, its injurious burnt air may be carried off, by a pipe inserted laterally into the larger door of the dome, and communicating at the other end, which should be raised eight or ten inches, with the chimney of the room ; all the other apertures of the dome being closed.

The furnace, thus charged, will keep up a moderate and nearly equal warmth for many hours, without injury or offence ; the charcoal burning down exceeding slowly ; and the heated balls or bricks continuing the warmth for a considerable time after the fuel is consumed. Fresh charcoal may be occasionally supplied through the door above the grate : the check, which the balls give to the motion of the air through the furnace, renders the consumption of this also slow, and it may still be made more so, at pleasure, by stopping a part of the aperture which



admits the air, or of the pipe or chimney which carries it off.

It appears from the foregoing account, that two black lead crucibles, fitted up in a manner which any common workman can easily execute, with a few additional parts as easily procurable, are sufficient for forming almost any kind of furnace which experimental enquiries have occasion for; and that they not only unite, like the different parts of other portable furnaces, into one furnace, but likewise, for sundry uses, form two distinct ones. It will be extremely convenient to have a third crucible prepared in the same manner: in which case, as no operation requires more than two; whatever kind of furnace is required for one operation, there will always be at least one left at liberty for another; so that two very different kinds of experiments may thus be going on at the same time, without hindrance, and without interfering one with another.

For enquiries of any considerable extent or multiplicity, it is necessary to be provided with several of these crucibles; and though, for general use, we have given the preference to those marked 60 on the bottoms, yet other sizes may be occasionally employed, and have their advantages for particular purposes: much smaller ones, down as far as number 20, will make, for some uses, very convenient furnaces. Those of number 60 may be considered as the mean size: they are as large as are wanted, in experimental practice, for a capella or bath; and they are the smallest, and most manageable, that will answer effectually as a wind furnace or blast furnace for strong fire. The largest black lead crucibles are marked 100: their internal height is about thirteen inches and a half, and their internal width at the mouth ten inches and a half. The next  
sizes

sizes are marked 90, 80, &c. without any intermediate numbers between the tens. All these are half an inch or more narrower one than the other, though not with any exact regularity in the diminution of the sizes, or in the dimensions of the pots of one number. Those of 90 or 100, with a hoop and rings adapted to them, will receive sand-pots, stills, &c. large enough for the purposes of the apothecary: but furnaces for experimental pursuits being the present object, it is sufficient here to have given a hint of this application of them.

It is expedient likewise, in a well-appointed laboratory, to have some furnaces of a different construction as well as of different magnitudes, set apart for particular uses, especially for those which demand great vehemence or continuance of fire.

IN all cases where vehement fire is to be continued for any considerable length of time, the furnace may be strengthened by inserting one of the crucibles into another of a larger size. Some of the thick bottom part of the inner crucible is to be sawed off, and the remainder rounded with a rasp, that its surface may in some measure correspond to the cavity of the outer one; and the mouth of this last is to be widened, if it does not sufficiently admit the wide part of the other, by rasping off a little from its inside all round the converging edge. Any crucible may thus be made to fit conveniently into the second size above it; that of number 60 into 80, 70 into 90, and 80 into 100. Such vacuity, as may remain between the two, is to be filled with dry sand dropt in at the sides; or rather with flaked lime, or fine sifted wood-ashes, diluted with so much water as will render them of a due consistence for being poured in. This mixture soon sets, without shrinking considerably, and without growing hard  
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in the fire : thus it uniformly fills the interstices, and joins the pots sufficiently together, yet not so firmly but that upon occasion they may be easily separated again.

The fuel, for producing or continuing vehement fire, should be the most ponderous and compact kind of charcoal, as that of the oak or beech, free from bark, and in pieces about the size of hens eggs. It should be kept ready lighted, for continual supplies, in another vessel, such as the open furnace formerly described ; and fresh quantities of the burning charcoal thrown in every seven or eight minutes, or in proportion to the quickness of the consumption, that the crucible may always continue covered. Where a dome is used, a supply of lighted fuel is commodiously obtained by means of an iron plate, turned up at the sides into a kind of square trough, and hooked on the fire-place door : the trough being filled with charcoal, the inner part of the coals is kindled by the vicinity of the fire, and this is moved into the furnace by successively pushing forward the unlighted part. Some have imagined that the supplying of fuel previously made red hot could affect only those kinds of operations, in which the vessel is set over the fire, and the fresh fuel interposed between the fire and its bottom ; and that this practice could be of no advantage in the melting furnace, where the crucible is placed in the middle of the fire. But though, in this last circumstance, the previous kindling of the fuel has much less influence than in the other, it is by no means to be disregarded : the upper part of the crucible may sometimes be nearly bare, and some of the pieces thrown in may drop down through vacuities about the sides ; in which cases it is obvious, that the injection of cold or unlighted coals, must necessarily, for a time, diminish the heat about the vessel, and likewise endanger its cracking.

If a pot is to be fitted up on purpose for a blast furnace, no other aperture is required than a round one in the side for the nose of the bellows to enter, the fuel being here thrown in at the top: all other apertures needlessly weaken the furnace. The pot should be of the largest size: if a cover or dome, or an additional part for enlarging its capacity, is wanted, another pot of the same size, with a portion of its lower narrow part sawed off, makes a very convenient one; and this narrow part, as we shall see hereafter, will be of use for another purpose. A round plate or slip, sawed from the solid part of the bottom, serves very commodiously both for a grate, and for a support to the crucible: eight or nine holes, about three quarters of an inch in diameter, are bored round the outer part of the plate, for the transmission of the air forced in by the bellows; and four or five small crucibles may be placed together in the middle: the holes are made to widen downwards, to prevent their being choked up by pieces of the fuel.

The bellows I have chiefly employed is the organ bellows; with this variation in its structure, that the upper board, instead of rising obliquely on hinges at one side, rises equally on all sides, and continues always horizontal. On account of the flexibility or pliability of the leather of this kind of bellows, it is not only moved far easier than the common ones, whose leathers are stiff, but is likewise free from their inconvenience of resisting unequally according to the greater or less extension of the folds. The board is pressed down, and the air forced out, by a weight on the top: in the common bellows this weight, pressing on an inclined plane, whose inclination is continually changing, has its force changing in  
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like manner, and thus produces an irregular blast, and an unsteady heat : in ours, the weight, acting always perpendicularly, has always an equal power, and the air is propelled in one unvaried current. The same advantage may be procured also to bellows of the common construction, by an alteration only in the disposition of the weight ; which, instead of being placed on the top, should be hung at the extremity, upon an arc, furnished with a groove for receiving the cord, and whose center is the point on which the board moves : the weight being thus made to act always in a perpendicular direction, and at an equal distance from the center of motion, an equality of its power is effectually secured. By these means, the heat is kept up uniform ; and may be easily increased at pleasure, by increasing the weights, to the greatest degree that can be excited in furnaces ; in which intention it will be of advantage to have the nozzle of the bellows wider than usual, that the air may be the more freely discharged from it. The bellows is of no incumbrance in the laboratory, being inclosed in a wooden case, whose cover does the office of a common table : to the nozzle, which just comes through the cross bar at the bottom of the table, is occasionally fitted a pipe reaching to the furnace.

The bellows thus disposed serves likewise for impelling and concentrating the flame of a lamp upon bodies exposed to it. For this purpose, an upright tin pipe is fitted on the nozzle by a short elbow at its lower end ; and at its upper end is a moveable elbow, into which is inserted a lesser pipe, having a very small aperture in its extremity : this aperture being applied to the flame of a lamp placed upon the table, and the pipe blown through ; the flame lengthens in the direction of the blast, and

converges into a small space, producing there a very intense heat. This application of a lamp is common among fundry artists, for melting or softening glass or metalline bodies in any particular part, without affecting the rest of the mass; as in soldering metals, making balls for thermometers, &c. It is likewise very commodious for the expeditious performance of many kinds of experiments, where only a small quantity of matter is to be acted upon by the heat: a little gold or silver, laid in a cavity made in a solid piece of charcoal, and exposed to the concentrated flame, melts almost instantaneously; and a little lead, placed in a cupel, may thus be quickly worked off or turned to scoria, so as to discover whether it contains any considerable proportion of the noble metals.

A bellows of the above construction is worked with very little labour. It is made still lighter and more commodious, by using a stiff rod, for moving the lower board, instead of the flexible cord or chain commonly employed. By the rod, its motion is made to follow that of the hand: whereas, with the cord or chain, it cannot sink fast enough without a considerable additional weight, and, in raising it again, the hand has this weight to overcome at the same time with the weight on the upper board by which the air is forced out.

The trouble of using bellows has by some been proposed to be dispensed with, by substituting the æolipile. This instrument is a strong copper vessel, with a neck turned to one side, and terminating in a very small aperture. The vessel being about half filled with water, and set on some burning charcoal, in any convenient little furnace, such as one of our pots, with its neck directed to, and placed at a small distance from, the fire to be excited; as soon as the water begins to boil, an

elastic vapour issues with vehemence through the small orifice, and the fire is animated in the same manner as by air impelled by bellows; whence this instrument has been called the æolian bellows and philosophers bellows. From this effect of the æolipile on an open fire, it has been imagined that it would perform the same office when its neck was inserted, like the nose of a common bellows, into the cavity beneath the grate of a furnace, and accordingly some practical writers have given figures of it as employed in this use. But on trial, I have constantly found it, when thus applied, instead of exciting, to extinguish the fire; and the event was the same, in all other cases, where the vapour did not pass through a portion of the atmosphere before its admission to the burning fuel. From this observation it may be presumed, that it is not the included matter, or any particular element in it, that animates fire, but the common air of the atmosphere which the watery vapour imbibes or propels before it. This mention is here made of the æolipile, to prevent others from being put to the expence and disappointment of such an apparatus as gave rise to these observations.

A CLOSE-bottomed pot, such as that used for the foregoing blast furnace, but without a grate, makes a furnace for the fusion of metals, the revival of metallic calces, and the smelting or assaying of ores, *trans carbones* as it is called, or in contact with the burning fuel, as practised in the large works. The furnace being intensely heated, and almost filled with fuel, some of the subject-matter is sprinkled upon the coals, chiefly about the middle, and towards the side opposite to the bellows, but with care that it no where touch the side: more charcoal is thrown over it; the fire, according to the nature of the subject, is either kept up strong, or abated a little, by lessening the

the weight upon the bellows ; and the alternate injection of the subject-matter and of charcoal continued. The metal and slag, melting and dropping down through the coals, are collected in the bottom : when they are of such a kind as to melt with difficulty, it is necessary, in order to their being continued in thin fusion, to direct the pipe of the bellows downwards, toward the opposite side of the bottom : the aperture is made to admit of the bellows being readily thus directed, without widening it in the middle, by sloping off a little, from its upper edge on the outside, and from the lower edge within.

When iron is thus to be melted (an intention for which this furnace is extremely well adapted) or copper to be purified, among the coals, the black lead pot performs the office both of a crucible and of a furnace. In this case it is necessary to have its bottom surrounded on the outside with burning fuel : the fittings and small fragments of charcoal, unfit for other uses, answer sufficiently for this purpose, for they are soon set on fire by the heat of the pot, and serve, as well as the larger pieces, to maintain and augment its heat : they may be placed in a cavity made in the ground, or in the bottom of another vessel. When the process is finished, the melted metal may be poured out, by inclining the pot, through the hole where the pipe of the bellows entered.

But when litharge is to be revived, or the ores of lead or of the other more fusible and destructible kinds of metals to be smelted, the metal, in proportion as it is collected in the bottom, must be suffered to run off from the vehement heat and blast of air ; for which purpose a passage is to be made for it in the most depending part, and a basin filled with coals placed conveniently on the outside for receiving it. The lower part of a black lead pot, sawed off at a proper height, as three or four inches above the

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the bottom of its internal cavity, makes a commodious basin for this use; and is easily made to join to the sloping canal in the furnace, by rasping off a little at one side, and forming a channel in the lip corresponding to the hole in the furnace: the juncture is secured by the interposition of a little softened loam or clay.

The more sulphureous ores are commonly freed, by roasting, from great part of their sulphur, before they are submitted to this operation: for, by this process alone, the sulphur would not be completely separated; and the metal, after the fusion, would prove impure and brittle, or be retained in great part among the slag. With our apparatus, the roasting is more particularly necessary, for the sake of the furnace as well as of the ore: for black lead crucibles, though they long sustain the action of vehement fire and of metals made fluid by it, are soon preyed upon and destroyed by sulphureous bodies in fusion.

The pot, employed as a furnace for these uses, should, like the preceding blast furnace, be of the largest size: and its height may be increased, by inverting over it a ring sawed from the upper part of another pot of the same size. By this addition to its height, the fuel thrown on the top will be kindled, and the subject heated, before they sink down into the body of the furnace; and the convergency of the upper part of the ring prevents the heat from spreading and annoying the operator, as it does from furnaces of a diverging mouth.

As the blast furnace, designed for intense fire, is made stronger than the pots of the general construction, by having no other aperture than that which receives the bellows pipe; it is in like manner expedient, for some particular uses, to have a stronger wind-furnace, with  
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only such holes as are essentially necessary, that it may be better able to support a long continuance of vehement fire.

The furnace for this intention consists of two large pots: the lowermost of which has only a round hole in the bottom for admitting air; and the upper one, or dome, a similar hole corresponding to the chimney, with a door in the side through which the fuel is put in. The furnace is placed upon an inverted pot, which has a hole in its top answering to that in the bottom of the furnace, another large one in its side, and its mouth ground smooth that it may apply itself every where close upon the flat stone or iron plate which serves as a stand for it. Into the side aperture of this lower pot, which is both the foot and ash-pit of the furnace, an iron pipe is inserted, somewhat wider than the widest part of the chimney, and two or three feet long, on the end of which may be fitted a wooden one of more considerable length. The whole of this pipe may be laid horizontal, so as to reach into an adjoining apartment; or rather, if there is a conveniency, the wooden pipe may be sunk perpendicularly through the floor into a room underneath, and the horizontal iron one joined laterally to it at the top: its use is for conveying into the furnace, instead of the adjacent air rarefied by the heat, the colder and denser air at a distance; and its effect in animating the fire will be in proportion to the coldness and denseness of the air to which it reaches.

In the above construction, I have endeavoured to give the wind furnace all the advantages it appears capable of receiving; and to supply, with black lead pots, the wind furnace, contrived by Mr. Pott, of the academy of sciences at Berlin, on purpose for experiments that require the utmost vehemence of fire, as the vitrification of earthy

earthy and stony bodies. I nevertheless apprehend, that furnaces on this principle, with all the advantages that can be given to them, will not be found equal, in regard to the intensity of the heat, to the blast furnace above described ; and that air may be supplied more effectually by a well contrived wide nosed bellows, than by any other means whatever. The pressure of the atmosphere, which actuates the wind furnace, is variable, and subject to many irregularities in its effect : but the power which animates the blast furnace, is entirely in the operators hands, and its effect may be increased or diminished, with certainty and regularity, by increasing or diminishing the force artificially applied. The wind furnace however has its conveniencies ; as the fire may be raised in it to a degree sufficient for most purposes that commonly occur, and continued without any other trouble than that of supplying fuel.

The structure of our general furnace, already described, unites in some measure the advantages of both kinds ; by affording an opportunity, when the wind furnace is at work, of occasionally animating its fire by the blast. The same convenience may be procured also in the wind furnace above described for vehement fire : a hole, made in the side of the foot or ash-pit, serves for admitting the bellows-pipe ; and the air-pipe is at the same time stopt by means of a moveable register in the end next the furnace. This register is a circular iron plate, fixt on an axis, which is placed across the pipe : the extremity of the axis projecting on the outside, the plate is thereby readily turned, so as either to allow a free passage for the air, or to close the whole bore of the pipe.

It is, in many cases, a very desirable point, to be able to collect the heat, diffused through a furnace, into one

particular part, or to concentrate its force upon the subject. Some have thought to effect this, by making the sides and dome of an elliptical or parabolic figure; expecting, from the mathematical properties of those figures, that the rays of fire, striking all over the internal surface, would be reflected back into a small focal space, in the same manner as the solar rays are concentrated by burning concaves. On the authority of those, who had recommended these kinds of furnaces, I prepared, many years ago, an elliptical one; which was figured with great care, not only in a moist state, but after it had been dried and burnt, by the revolution of a semi-elliptical plane about its axis. In the effects of this furnace, I was greatly disappointed: for it could not be observed, that any focal reflexion obtained in it; or that any advantage resulted from the exactness of its figuration, or from the precise species of its curvature. And indeed many causes, which it is foreign to the present purpose to enter into a discussion of, concur in preventing both the regular reflection of the rays of heat in furnaces, and the collection and union of those which have been so reflected.

Others have attempted this concentration of fire upon a different principle. By blowing a stream of air through the flame of a lamp or candle, the flame, as already observed, is made to converge into a kind of focal point, and acts there with a great increase of its force: by multiplying these streams of flame, or impelling a number of flames into one point, the heat may be augmented to a very high degree. In furnaces also, the flame, and the most considerable part of the heat, follow the direction of the current of air: and hence it has been proposed to impel streams of air, from different parts of the circumference of the fuel, to the middle, by means of several bellowses placed round the furnace. Though the principle,

ple, however, appears to be a just one, the application of a number of bellows is too incommodious to be put in practice ; and by their disposition in one plane, round the furnace, great part of the fuel lies without their reach. I have therefore endeavoured to improve the contrivance ; to multiply the streams of air, to throw them in from almost all parts of the surface, to supply them all from one bellows, and in such a manner that they may not obstruct one another, but conspire as it were into one stream about the crucible.

The pot, which serves as a furnace for this purpose, has a number of holes, bored at small distances, in spiral lines, all over it, from the bottom, up to such a height as the fuel is designed to reach to. The crucible is placed, upon a proper support, in the bottom ; and the holes are made, not in a perpendicular direction to it, but oblique, that the streams of air forced in through them may but just touch it : by this means, the crucible stands out of danger of being cracked by the blast, and the impelled heat plays in a kind of spiral upon its surface. The pot, which served before for the blast-furnace, with an iron ring on its top, receives this perforated pot so far, that all its holes hang in the cavity ; which cavity having no other outlet than the round aperture for the bellows, the air, blown in through this aperture, necessarily distributes itself through the perforations of the inner pot. The inner pot may be of the largest size, as well as the outer one, the lower narrow part of the former falling into the upper wide one of the latter : it wants no addition to increase its height, but on the contrary will be more commodious, in regard to the inspection and taking out of the crucible, if all the part above where the fuel reaches to is sawed away : the most convenient cover for it is an iron plate,

with a round hole in the middle, and a handle projecting at one side for lifting it by.

The force of the fire being thus, in great measure, concentrated upon the crucible in the middle of the fuel; the crucible is heated, expeditiously, and with a little quantity of fuel, to a very intense degree, while the exterior parts of the fuel are of no great heat, and permit the operator to approach without incommoding him.

IN the use of the furnaces hitherto described, the attendance of the operator is necessary, both for inspecting the processes, and for supplying and animating the fuel. There are some operations of a slower kind; which require a gentle heat to be continued for a length of time; which demand little attendance in regard to the operations themselves; and in which, of consequence, it is extremely convenient to have the attendance in regard to the fire, as much as possible, dispensed with. This end is answered by the furnace called the athanor; an account of which is referred to another part of this work, as it cannot well be formed out of black lead pots, and does not fall in with the simplicity of the present contrivances.

Sundry attempts have been made for keeping up a continued heat, with as little trouble as in the athanor, by the flame of a lamp; but the common lamp-furnaces have not answered so well as could be wished. The lamps require frequent snuffing, and smoke much; and the soot, accumulated on the bottom of the vessel placed over them, is apt, at times, to fall down and put out the flame. The largeness of the wick, the irregular supply of oil from the reservoir by jets, and the oil being suffered to sink considerably in the lamp, so that the upper part of the wick burns to a coal, appeared to be the principal causes.

causes of these inconveniences ; which, accordingly, were found to be in great measure remedied by the following construction.

The lamp consists of a brass pipe, ten or twelve inches long, and about a quarter of an inch wide, inserted at one end into the reservoir of the oil, and turned up at the other to an elbow, like the bole of a tobacco-pipe, the aperture of which is extended to the width of near two inches. On this aperture is fitted a round plate, having five, six or seven small holes, at equal distances, round its outer part, into which are inserted as many pipes about an inch long : into these pipes are drawn threads of cotton, all together not exceeding what in the common lamps form one wick : by this division of the wick, the flame exposes a larger surface to the action of the air, the fuliginous matter is consumed and carried off, and the lamp burns clear and vivid.

The reservoir is a cylindric vessel, eight or ten inches wide, composed of three parts, with a cover on the top. The middle partition communicates, by the lateral pipe, with the wicks ; and has an upright open pipe soldered into its bottom, whose top reaches as high as the level of the wicks ; so that, when this part is charged with oil, till the oil rises up to the wicks in the other end of the lamp, any further addition of oil will run down through the upright pipe into the lower division of the reservoir. The upper division is designed for supplying oil to the middle one ; and, for that purpose, is furnished with a cock in the bottom, which is turned more or less, by a key on the outside, that the oil may drop fast enough to supply the consumption, or rather faster, for the overplus is of no inconvenience, being carried off by the upright pipe ; so that the oil is always, by this means, kept exactly at the same height in the lamp. For common uses,  
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the middle division alone may be made to suffice ; for, on account of its width, the sinking of the oil will not be considerable in several hours burning. In either case, however, it is expedient to renew the wicks every two or three days ; oftener or seldomer, according as the oil is more or less foul ; for its impure matter, gradually left in the wicks, occasions the flame to become more and more dull. For the more convenient renewing of them, there should be two of the perforated plates ; that, when one is removed, another, with wicks fitted to it, may be ready to supply its place.

One of the black lead pots, described at the beginning of this paper, makes a proper furnace for the lamp. If one is to be fitted up on purpose for this use, it requires no other aperture than one in the bottom for admitting air, and one in the side for the introduction of the elbow of the lamp : the reservoir stands on any convenient support without the furnace. The stopper of the side aperture consists of two pieces, that it may be conveniently put in after the lamp is introduced ; and has a round hole at its bottom fitting the pipe of the lamp. By these means, the furnace being set upon a trevet or open foot, the air enters only underneath, and spreads equally all round, without coming in streams, whence the flame burns steady. It is not advisable to attempt raising the heat higher than about the 450th degree of Fahrenheit's thermometer, a heat somewhat more than sufficient for keeping tin in perfect fusion. Some have proposed giving a much greater degree of heat in lamp furnaces, by using a number of large wicks ; but when the furnace is so heated, the oil emits copious fumes, and its whole quantity takes fire. The balneum, or other vessel including the subject-matters, is supported over the flame by an iron ring, as already described in the sand bath  
and



and still : a bath is here particularly necessary, as the subject would otherwise be very unequally heated, only a small part of the vessel being exposed to the flame.

THE use of baths in general is for defending the glass or other vessels, placed in them, from the immediate action of the fire, and for preventing their being suddenly affected by variations of the heat. There is one imperfection in sand and other solid intermedia; that their heat is by no means uniform, but different in their different parts, decreasing gradually from the bottom to the top; this is always the case, even when the fire is uniformly distributed round the vessel by the contrivances formerly described. In those circumstances therefore, wherein it is expedient to secure with certainty an equality of the heat, recourse must be had to fluid intermedia. The water bath, commonly employed in this intention, is confined to low degrees of heat; a boiling heat being the utmost that water is susceptible of. I have therefore, on some occasions, made use of another fluid, quicksilver; which bears a degree of heat exceeding that of boiling water, above twice as much, as the heat of boiling water does that of freezing water.

The mercurial bath is prepared with two iron pots or ladles, of such sizes, that one may be received into the other, so as to leave a vacuity between them all round: this space is filled with quicksilver, the two vessels being properly secured together by pins passed through the edges, to prevent the inner one from being buoyed up by the quicksilver. The vacuity may be so small, that a little quantity of mercury shall suffice; and the expence of this article may be further lessened, by using, instead of pure mercury, a composition of it with about half its weight of lead, or with so much as it will bear without losing

its fluidity in a moderate warmth. In this kind of bath, all the parts of the inner vessel will be equally heated, how unequally soever the fire be applied underneath; and the heat may be increased nearly as far as that in which lead begins to melt, without any danger of the mercury evaporating. The mercurial thermometer of Fahrenheit, whose 32d division is the point at which water freezes, and the 212th that at which water boils, is raised by the heat in which lead melts to about the 550th division, and by the heat of quicksilver boiling and evaporating to the 600th.

Though the heat, of which mercury is susceptible, is great in comparison with that of boiling water, it is far too little for many purposes for which baths are wanted. Some curious workmen, for communicating these greater degrees of heat equally to different subjects, as where a number of small steel instruments is to be equally tempered, employ melted lead as an intermedium. A plate of iron floats upon the melted lead, and receives therefrom, in all its parts, an equal heat: the pieces of steel, laid upon this plate, acquire all at once the same degree of heat, and are at once quenched in water; the blue or other colours, which they successively assume, affording sure marks of the proper points of heat at which they are to be quenched, according to the different degrees of hardness required in them.

From this practice I took the hint of another metallic bath, which supplies at once both the mercurial and the lead baths. As the imperfection of mercury consists in its not bearing so great a heat, and that of lead in its not becoming fluid with so small a one, as many purposes require; I have substituted one of the fusible metallic mixtures, mentioned by Sir Isaac Newton in the Philosophical Transactions, composed of two parts of lead, three  
of

of tin, and five of bismuth, melted together : one pot or ladle being fixed into another, in the same manner as for the mercurial bath, the space between them is filled with the melted compound. This mixture proves fluid in a heat very little greater than that in which water boils; and consequently serves as an intermedium for all degrees of heat above this period, up to that in which the metal itself grows red hot and boils; a heat greater than baths are ever wanted for in practice.

THE foregoing furnaces I have used with pleasure for many years; and experienced their commodiousness, in public as well as private operations, for continued and extensive enquiries, as well as for occasional experiments. Eight or ten pots have stood at work together, under a common chimney; and others, upon a stand, in the middle of the room, with a copper dome, of a conical figure, over them, which communicated with the chimney by a pipe bent at right angles: by this means the processes could be freely inspected, without any danger of injury or offence from burnt air or fumes, which, as soon as the chimney became somewhat warm, were completely carried off. It is convenient to have the dome made to slide easily up and down the perpendicular part of the pipe; which may be effected by suspending it to two chains passed over pulleys fixed to the ceiling and loaded with a counterpoise.

We flatter ourselves, that the publication of a simple apparatus, easy of construction, of little expence, commodious in its use, and easily manageable in all its forms and combinations, will contribute to remove one of the chief obstacles to chemical researches, and to promote those kinds of experimental pursuits in which furnaces are a principal instrument.

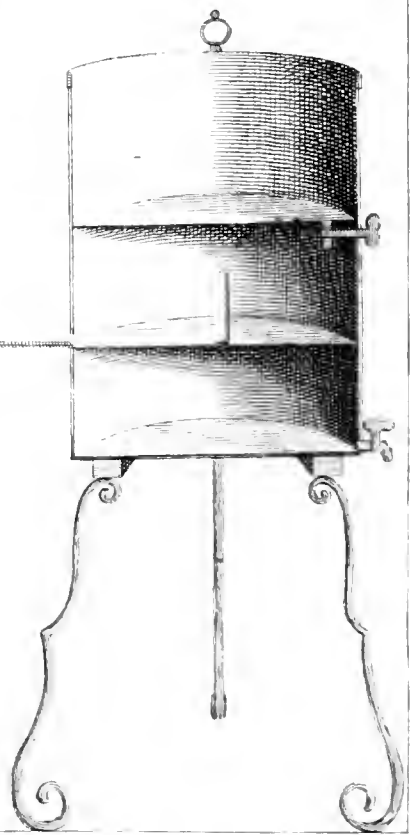
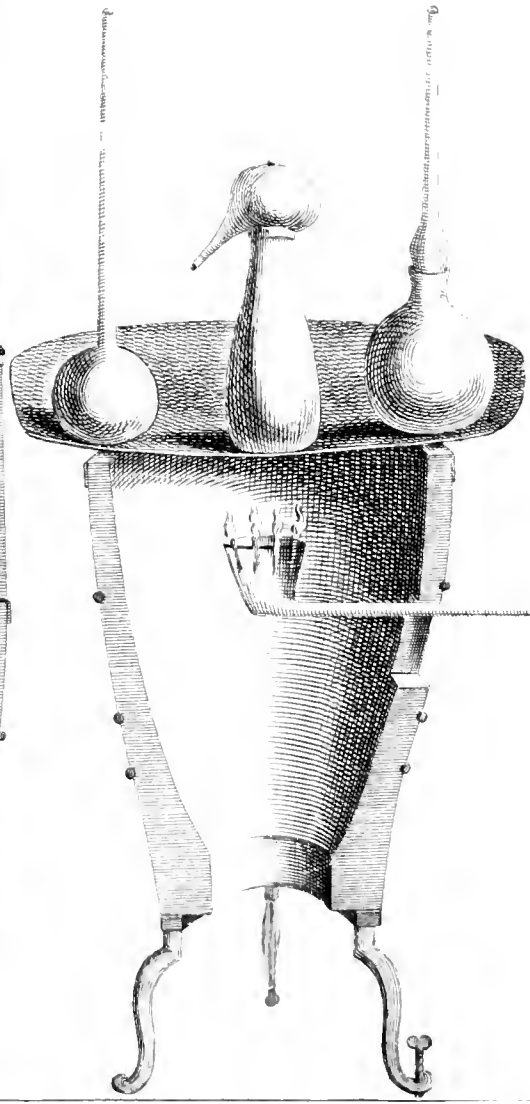
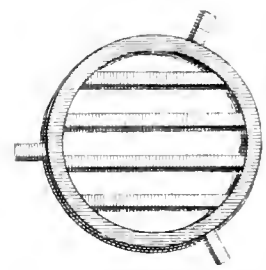
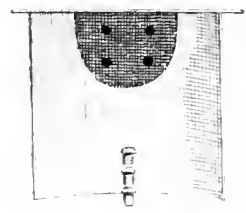
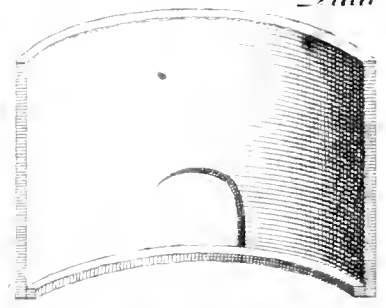
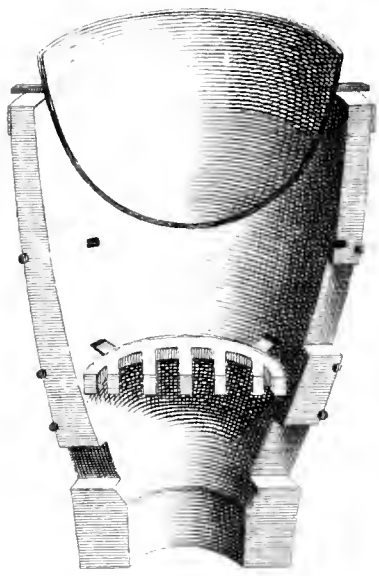
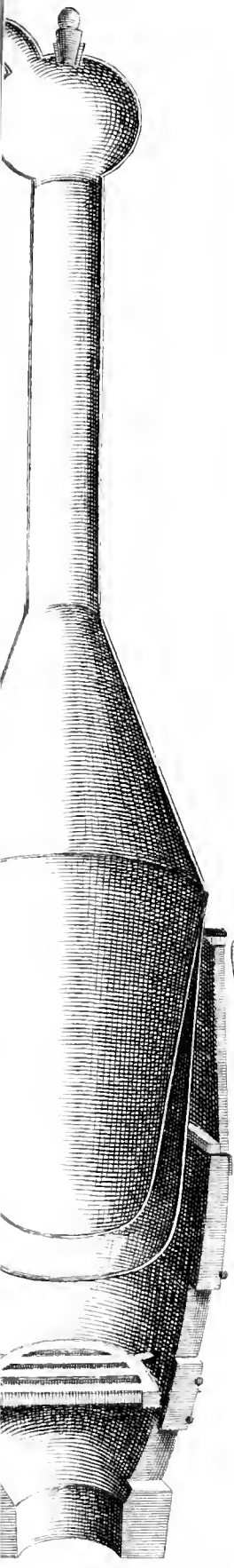
*Explanation of PLATE I.*

**T**HE upper figure on the right side of the plate is a perpendicular section of the iron hoop, see page 7, with the aperture shewn in its back part. Under it is a plan of the door of the aperture, rivetted on an iron plate.

Under this, is a plan of the middle grate, with three pins projecting from its circumference. The lower grate differs only in being smaller; and the upper one, in being larger, and having no pins.

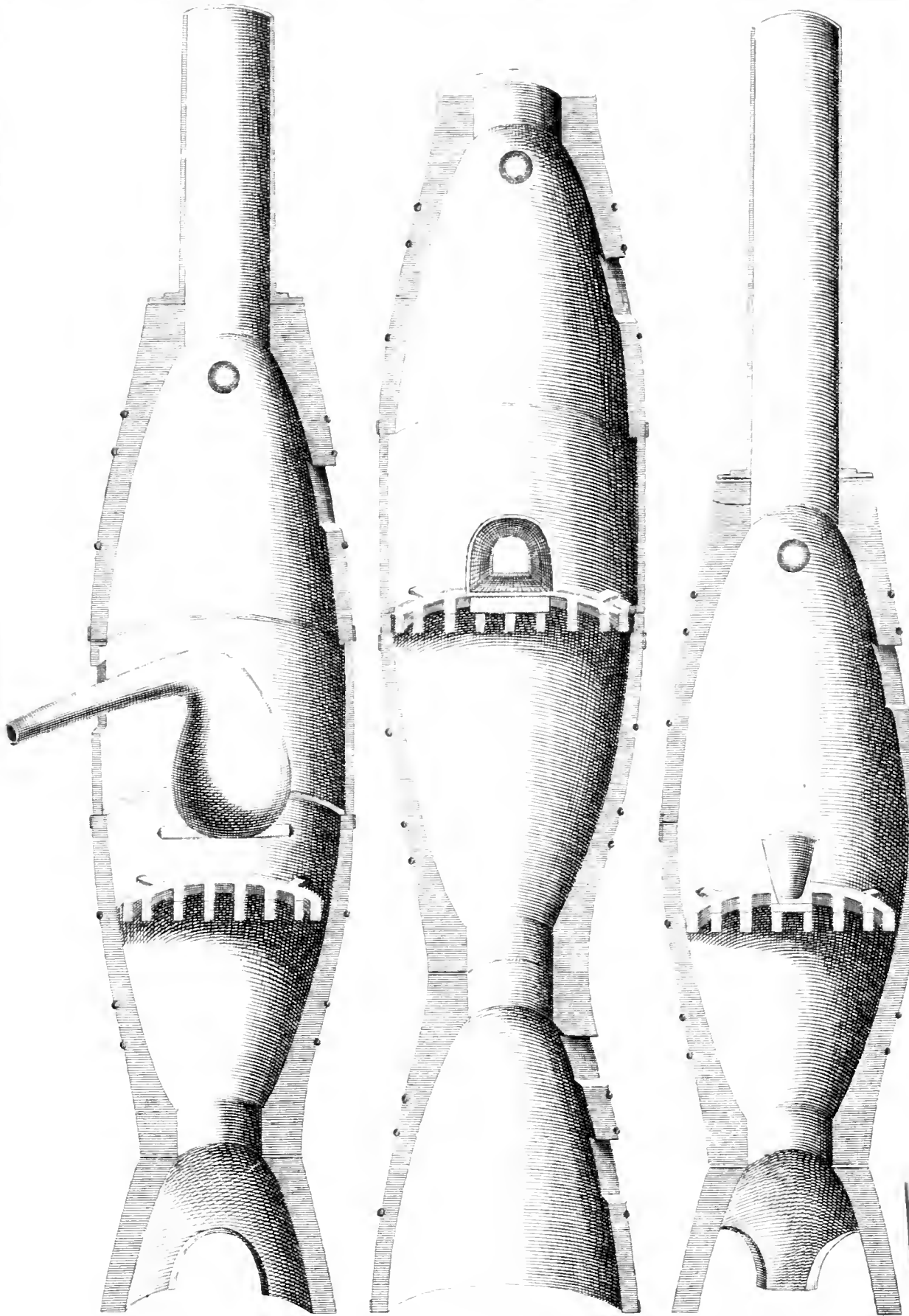
The middle figure in the upper part of the plate is a perpendicular section, with a perspective view of the back part, of one of the black lead pots, of the size marked 60, as fitted for the general purposes of furnaces; with the smaller grate, cut across the bars, in its lower part; and an iron pot hung in its mouth, see page 8. It is drawn, as all the other figures in this and the following plates, to about one fifth of the real size. The notches for the grates, and all the apertures, are here expressed: but in the other figures, only those apertures are shewn, which are necessary for the respective uses to which the furnaces are applied. They are all bound, in three places, with copper wire; and round the mouth is a thin copper hoop, which preserves the outer edge from wearing off.

On the left side of the plate is represented the apparatus for distillation, described in page 9: and on the right is the lamp, communicating with its reservoir (see page 29) by a lateral pipe, which is here made a little too short for want of room on the plate. Over the lamp furnace is a broad pan; which is here employed as a water-bath, and contains a long-necked matras or bolthead; a more commodious vessel of the same kind composed of a glass receiver with a long pipe inserted into its mouth; and a cucurbit or body with a glass head for distillation.











*Explanation of* PLATE II.

**I**N this plate are shewn different combinations of the pots for different uses, with and without the iron hoop between them. In the back part of the upper pot or dome is expressed the round hole, through which, and the opposite ash-pit door, an iron rod is passed for conveniently lifting it off when hot.

On the right hand is the wind melting furnace (page 11) with a section of the grate and crucible. It stands upon a portion of another pot, in the sides of which three arches are sawed (page 6).

In the middle is the assay furnace (page 12) with a section of the muffle above the grate. This furnace stands upon another entire pot inverted, that it may be raised to a proper height for the inspection of the cupels, &c. under the muffle.

On the left hand is a reverberatory, with a coated glass retort for distillation. It stands on the same kind of foot as the wind furnace on the right side; and in its back part is shewn one of the two bars on which the bottom of the retort is supported.

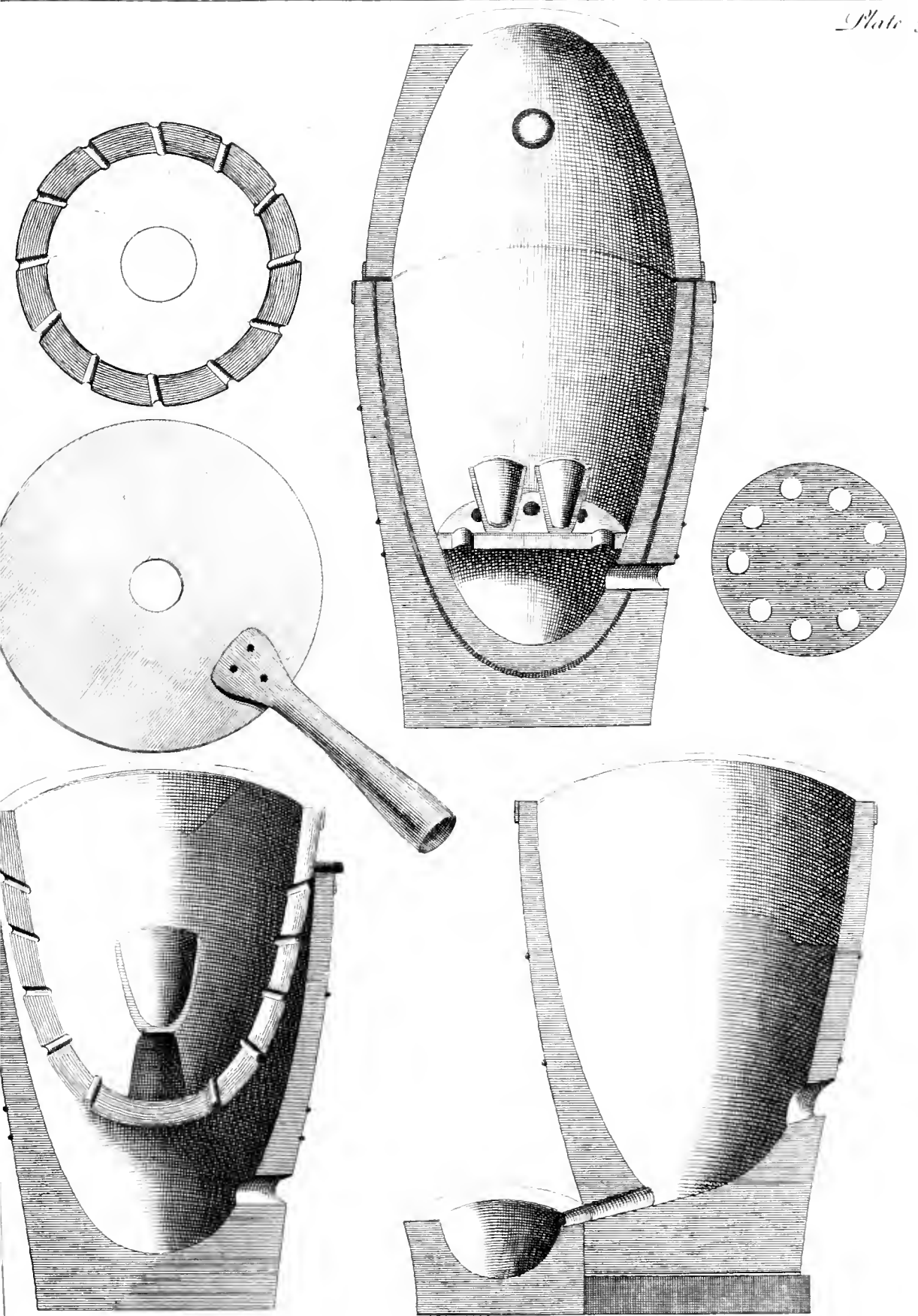
*Explanation of* PLATE III.

**T**HE three furnaces in this plate are different kinds of blast furnaces; with holes bored in the sides for receiving the nose of the bellows.

The uppermost consists of a pot of the size marked 80, fitted into one of 100; with a portion of another of 100 inverted over it for a dome. So much of the bottom of this last is sawed off as to procure a sufficient aperture; and so much is sawed from the mouth, that the remainder may be of a proper width to fit upon the mouth of the lesser pot. A round slip, sawed from the bottom, serves both for a grate and for a support to the crucible (page 18). A section of this grate is shewn in the furnace, and a plan of it on the right hand.

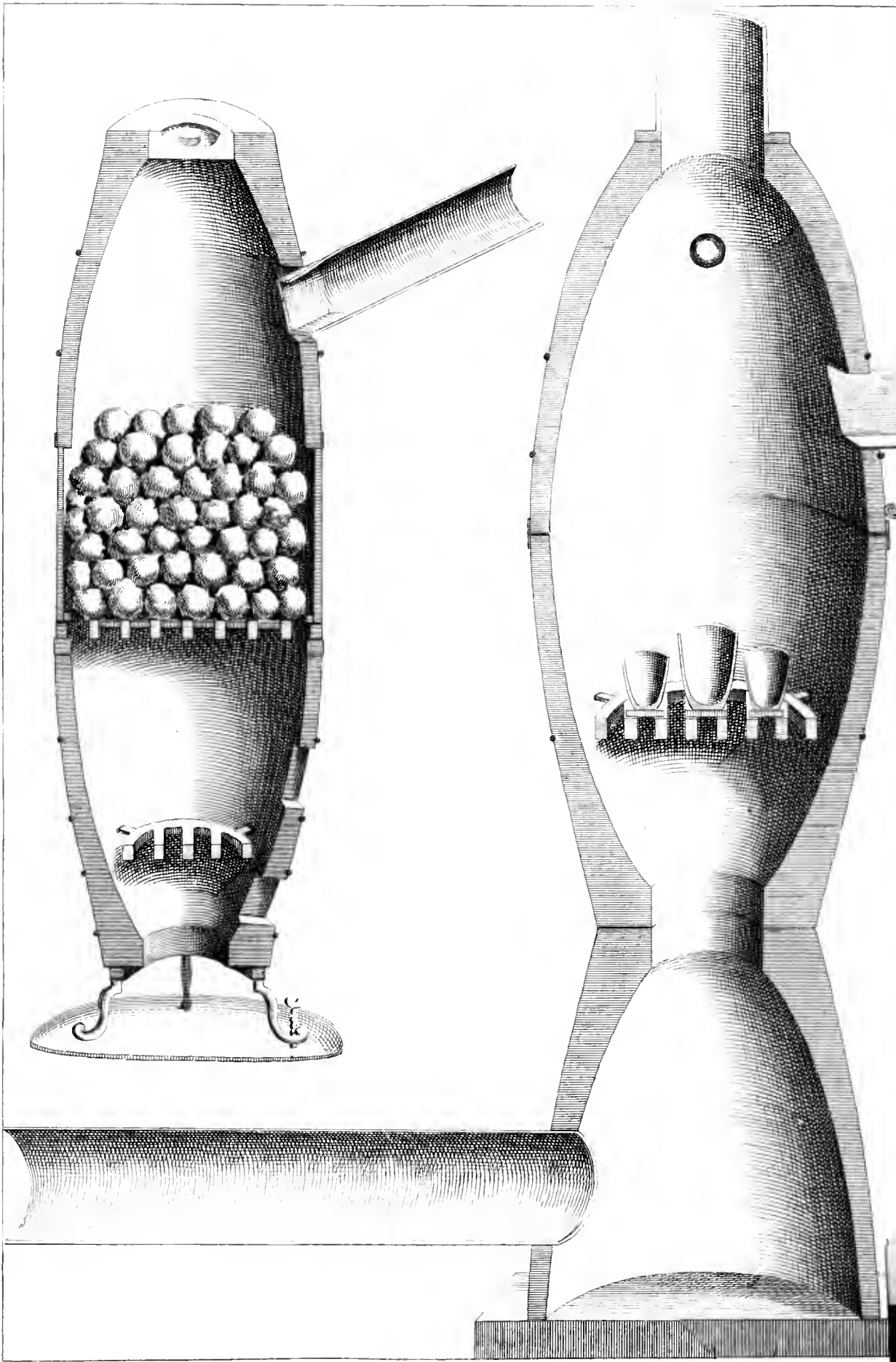
The right side furnace at the bottom of the plate is for fusion without a grate or among the fuel. The pot is of the largest size, and its height may be occasionally enlarged by the ring cut off from the dome of the foregoing furnace. To the sloping canal in its bottom is fitted the lower part of another pot. See page 21.

The lowermost furnace on the left hand is that described in page 27, in which streams of air are impelled from different parts of the fuel upon the crucible in the middle. The lower pot is that which serves for the blast furnace in the upper part of the plate; and the perforated pot is of the size 90, with its bottom rounded, and a part of the top cut off for the greater convenience of inspecting or taking out the crucible. The circular plane over it is an iron plate, with a hole in the middle, which serves as a cover for the pot; and over this is a transverse section of the perforated pot and crucible, to shew the direction of the streams of air.









*Explanation of* PLATE IV.

**T**HE furnace on the right side of the plate is the wind-furnace described in page 24 ; composed of the largest-sized black lead pots ; and constructed on the model of that used by Mr. Pott in his experiments of the vitrification of earthy bodies. A portion of the air pipe is shewn inserted into the foot, and five little crucibles upon the grate. To the door is fitted an iron plate, turned up at the sides, for receiving the fuel, which is kindled fast enough by the vicinity of the fire, to afford a constant supply of burning charcoal : the kindled part at the door is moved into the furnace by pushing the rest forward with an iron rod, and more unlighted charcoal is successively supplied behind.

The figure on the left side of the plate is that of the stove for warming a room, page 14. It stands on the iron trevet, with the flat iron pan underneath for receiving the ashes. The hoop is filled with balls of baked earth, which are supported by the large grate on the top of the lower pot. Into the door of the dome is inserted the square end of the iron pipe, the other end of which communicates with the chimney of the room.

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## II. HISTORY of GOLD,

And of the various ARTS and BUSINESSES  
depending thereon.

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### S E C T. I.

*Of the colour of Gold, and the methods of restoring its  
lustre, when sullied.*

**T**HE bright deep yellow colour of gold, commonly distinguished by its name, is one of the most obvious characters of this metal. Its colour and beauty are of great durability, being injured neither by air nor moisture, nor by any kind of exhalations that usually float in the atmosphere; as may be observed in the gildings of some public edifices, which have resisted the weather, and the vapours of London, and other populous cities, for half a century or more. In this property consists great part of the excellence of this metal for ornamental and some mechanic uses: there is no other malleable metallic body, so little susceptible of tarnish or discoloration, or so little disposed to communicate any stain to the matters which it lies in contact with.

As instruments or ornaments of pure gold are liable to be sullied only from the simple adhesion of extraneous substances; their beauty may be recovered, without any injury to the metal, however exquisitely figured, or without any abrasion of its surface, however thin and delicate,  
by



by means of certain liquids which dissolve the adhering foulness; as solution of soap, solution of fixt alkaline salts or alkaline ley, volatile alkaline spirits, and rectified spirit of wine.

In the use of the alkaline liquors, some caution is necessary in regard to the vessels; those of some metals being, in certain circumstances, corroded by them, so as remarkably to discolour the gold. A gilt snuff-box, boiled with soap-boilers ley in a tin pot, to clean it from such foulness as might adhere in the graven figures, and to prevent any deception which might hence arise in a hydrostatic examination of it, became soon of an ill colour, and at length appeared all over white as if it had been tinned: some pieces of standard gold, treated in the same manner, underwent the same change: and on trying volatile alkaline spirits, prepared with quick-lime, the same effect was produced more speedily. On boiling the pieces, thus whitened, with some of the same kind of alkaline liquors, in a copper vessel, the extraneous coat disappeared, and the gold recovered its proper colour.

For laces, embroideries, and gold thread woven in silks, the alkaline liquors are in no shape to be used; for, while they clean the gold, they corrode the silk, and change or discharge its colour. Soap also alters the shade, and even the species of certain colours. But spirit of wine may be used without any danger of its injuring either the colour or quality of the subject, and in many cases proves as effectual, for restoring the lustre of the gold, as the corrosive detergents. A rich brocade, flowered with a variety of colours, after being disagreeably tarnished, had the lustre of the gold perfectly restored by washing it with a soft brush dipt in warm spirit of wine; and some of the colours of the silk, which were likewise soiled, became at the same time remarkably bright and lively. Spirit of wine  
seems

seems to be the only material adapted to this intention, and probably the boasted secret of certain artists is no other than this spirit disguised : among liquids, I do not know of any other, that is of sufficient activity to discharge the foul matter, without being hurtful to the silk : as to powders, however fine, and however cautiously used, they scratch and wear the gold, which here is only superficial and of extreme tenuity.

But though spirit of wine is the most innocent material that can be employed for this purpose, it is not in all cases proper. The golden covering may be in some parts worn off ; or the base metal, with which it had been iniquitously alloyed, may be corroded by the air, so as to leave the particles of the gold disunited ; while the silver underneath, tarnished to a yellow hue, may continue a tolerable colour to the whole : in which cases it is apparent, that the removal of the tarnish would be prejudicial to the colour, and make the lace or embroidery less like gold than it was before. A piece of old tarnished gold lace, cleaned by spirit of wine, was deprived, with its tarnish, of greatest part of its golden hue, and looked now almost like silver lace.

Though no one of the other metallic bodies, singly, has any degree of the beautiful yellow colour which glows in gold, the true gold yellow may, nevertheless, be pretty nearly imitated, by certain combinations of other metals, particularly of copper with zinc. But how nearly soever these compositions approach to gold in degree or species of colour, they differ greatly in its durability ; and their differences in other respects are still more strongly marked, and of more easy discovery, as will appear in the sequel of this treatise.

## S E C T. II.

*Of the gravity of Gold.*

**F**INE gold, immersed in water, weighs near one nineteenth part less than in air, and consequently it is upwards of nineteen times heavier than equal its own volume of water. All the other kinds of matter, that have been known till of late years, are of remarkably less gravity; mercury, the next in weight, being only about fourteen times heavier than water, and lead, the next of the solid bodies, little more than eleven times. Hence the gravity of gold has been univervally reckoned one of its most certain and inimitable characteristics: and accordingly it has been laid down as an axiom, that whatever body exceeded the weight of water above fourteen times, how unpromising soever in appearance, must necessarily contain gold. The discovery of the ponderous metal platina has now afforded an exception to this axiom, and shewn that weight alone is no certain criterion of gold; for pure platina, perfectly void of gold, is nearly as ponderous as the precious metal itself.

The specific gravity of gold, or its comparative weight to an equal volume of water, is by some reported to be 19,640, and in a paper in the Swedish transactions it is made no less than 20,000; that of water being 1,000. But in the experiments of Mr. Ellicott, whose accuracy and skill are unquestionable, made upon gold supposed to be fine, it did not exceed 19,207; and of different masses of gold, which I had refined to the greatest degree of purity that I apprehend gold capable of being brought to, and well hammered, I found the gravity, on many different trials, between 19,300 and 19,400. A mass of fine gold, weighing in air 13447, being weighed in distilled

filled water of the temperature of fifty three degrees of Fahrenheit's thermometer, or twenty one 180ths of the interval between freezing and boiling; the loss in water was 694, whence the gravity turns out 19,376; the balance, thus loaded, turned sensibly with half of one of the weights, so that the true loss in water could not be half a weight more or less than the apparent, and the gravity, of consequence, could not be so little as 19,362, or so much as 19,390. It were to be wished that those, who have examined metals hydrostatically, had specified the sensibility of the balance, and the quality and warmth of the water. An increase of heat rarefying water much more than it does gold, the gold must turn out proportionably heavier than an equal volume of the expanded fluid; and this difference is perhaps more considerable than it has generally been supposed. From freezing to boiling water, or by an augmentation of heat equivalent to one hundred and eighty degrees of Fahrenheit's thermometer, a rod of gold appears to be lengthened about one part in 700, and consequently its volume is increased about one part in 233, while the volume of water is increased one 26th or more: hence by an augmentation of forty degrees of the thermometer, or from a little above freezing to the summer heat, the volume of gold, if its expansion be uniform, is increased one part in 1048, and that of water one in 117; and the gravity of gold, weighed in the water so warmed and expanded, should be greater than when the gold and water are forty degrees colder, in the proportion of about 19,265 to 19,400. This calculation gives a difference, in the gravity, of 0,034 for every ten degrees of the thermometer, but some trials seemed to make it greater. A piece of gold being weighed in water of fifty degrees, and afterwards in the same water made eighty eight degrees hotter, in which  
it

it was kept immersed for some time to acquire its warmth, the gravities turned out 19,372 and 19,769; whence the difference for every ten degrees comes to be 0,045—If the mean gravity of gold be reckoned 19,300; as a cubic inch of water weighs about 254 grains, a cubic inch of gold will weigh of consequence about 4902 grains or ten ounces and a hundred and two grains.

As air resists the descent of bodies more or less in proportion to its own gravity and the surface of the descending body, and as the brass, of which weights are made, is more than double in volume to an equal weight of gold; it follows, that if gold be counterpoised with brass weights in light air, the gold will preponderate when the air grows heavier, the addition made to the air's gravity resisting the brass above twice as much as it does the gold. It has hence been imagined, that the comparative gravity of gold to brass weights must be so far influenced by the variable gravity of the atmosphere, that there must be an advantage in buying gold by weight when the air is lightest. The difference appears however too inconsiderable to be regarded in a commercial view. For the loss of weight of the two metals in the air being as much less than their loss in water, as air is lighter than water; and air, as appears from an experiment of Mr. Hawksbee, being in its lightest state about a 937th, and in its heaviest about an 848th part of the weight of water; it will be found on calculation, that the gold preponderates above the brass, in the heaviest more than in the lightest air, only by one part in 145000, or one grain in about three hundred and two ounces: a difference too minute to be sensible in the tenderest balance.

Notwithstanding the great density of gold, and its containing, under an equal volume, the greatest quantity of solid parts of all known bodies; it is said, that it not

only freely transmits the magnetic effluvia, but that even water, by strong pressure, may be squeezed through its pores. A hollow sphere of gold being filled with water, foldered up, and pressed with great force, the water was found to transfuse in multitudes of small drops, which covered the outside of the sphere like dew. This experiment was made by the Florentine academy, and is mentioned by Sir Isaac Newton on the testimony of an eyewitness. It may be questioned however, whether the interstices, through which the water issued, were the pores proper to the gold in its natural state; or whether they were not rather an enlargement of its natural pores, occasioned by the parts of the metal having been forced asunder by the incompressibility of the water, and the violence of the pressure.

### S E C T. III.

*Of the ductility of Gold, and the arts depending on this property: Gold-beating, wire-drawing, gilding with gold-leaf on different subjects.*

**F**INE gold is a soft metal; easily chiseled, cut, or graved; very flexible; and so tough, that when at length made to break by repeated bendings backwards and forwards, the fracture, on each of the pieces, appears drawn out in the middle like a wedge. It takes impressions from dyes in great perfection; does not file freely, but sticks in the teeth; has little elasticity or sonorousness; receives great splendor from the burnisher, but does not appear so bright from the polishing stone. It yields freely to the hammer, both when hot and cold, and admits of being stretched to a vast extent.

The great value which has at all times been fixed on gold, its beautiful colour, incorruptibility, and compactness, render its ductility an object of primary importance:  
on

on this depend fundry arts and manufactures, in which we see it extended to an amazing tenuity, and variously applied on the surface of other bodies, both for their ornament and preservation.

*Preparation of Gold leaf.*

THE gold is melted in a black lead crucible, with some borax, in a wind furnace, called by the workmen a wind-hole : as soon as it appears in perfect fusion, it is poured out into an iron ingot mould, six or eight inches long, and three quarters of an inch wide, previously greased, and heated, so as to make the tallow run and smoke, but not to take flame. The bar of gold is made red hot, to burn off the unctuous matter, and forged on an anvil into a long plate, which is further extended, by being passed repeatedly between polished steel rollers, till it becomes a ribbon, as thin as paper. Formerly the whole of this extension was procured by means of the hammer, and some of the French workmen are still said to follow the same practice : but the use of the flattening mill both abridges the operation, and renders the plate of more uniform thickness. The ribbon is divided by compasses, and cut with sheers into equal pieces, which consequently are of equal weights : these are forged on an anvil till they are an inch square, and afterwards well nealed, to correct the rigidity which the metal has contracted in the hammering and flattening. Two ounces of gold, or 960 grains, the quantity which the workmen usually melt at a time, make an hundred and fifty of these squares, whence each of them weighs six grains and two fifths ; and as 4902 grains of gold make a cubic inch, the thickness of the square plates is about the 766th part of an inch.

In order to the further extension of these pieces into fine leaves, it is necessary to interpose some smooth body  
between

between them and the hammer, for softening its blow, and defending them from the rudeness of its immediate action : as also to place between every two of the pieces some proper intermedium, which, while it prevents their uniting together, or injuring one another, may suffer them freely to extend. Both these ends are answered by certain animal membranes.

The gold-beaters use three kinds of membranes; for the outside cover, common parchment, made of sheep-skin; for interlaying with the gold, first the smoothest and closest vellum, made of calves-skin; and afterwards the much finer skins of ox-gut, stript off from the large streight gut slit open, curiously prepared on purpose for this use, and hence called gold-beaters skin. The preparation of these last is a distinct business, practised by only two or three persons in the kingdom, some of the particulars of which I have not satisfactorily learnt. The general process is said to consist, in applying one upon another, by the smooth sides, in a moist state, in which they readily cohere and unite inseparably; stretching them on a frame, and carefully scraping off the fat and rough matter, so as to leave only the fine exterior membrane of the gut; beating them between double leaves of paper, to force out what unctuousity may remain in them; moistening them once or twice with an infusion of warm spices; and lastly drying and pressing them. It is said, that some calcined gypsum, or plaster-of-paris, is rubbed with a hares-foot both on the vellum and the ox-gut skins, which fills up such minute holes as may happen in them, and prevents the gold leaf from sticking, as it would do to the simple animal membrane. It is observable, that notwithstanding the vast extent to which the gold is beaten between these skins, and the great tenuity of the skins themselves, yet they sustain continual repetitions of the



process for several months, without extending or growing thinner. Our workmen find that after seventy or eighty repetitions, the skins, though they contract no flaw, will no longer permit the gold to extend between them; but that they may be again rendered fit for use by impregnating them with the virtue which they have lost, and that even holes in them may be repaired by the dextrous application of fresh pieces of skin: a microscopical examination of some skins that had been long used plainly shewed these repairs. The method of restoring their virtue is said in the *Encyclopedie* to be, by interlaying them with leaves of paper moistened with vinegar or white wine, beating them for a whole day, and afterwards rubbing them over as at first with plaster-of-paris. The gold is said to extend between them more easily, after they have been used a little, than when they are new.

The beating of the gold is performed on a smooth block of black marble, weighing, from two hundred to six hundred pounds, the heavier the better, about nine inches square on the upper surface, and sometimes less, fitted into the middle of a wooden frame, about two feet square, so as that the surface of the marble and the frame form one continuous plane. Three of the sides are furnished with a high ledge; and the front, which is open, has a leather flap fastened to it, which the gold-beater takes before him as an apron, for preserving the fragments of gold that fall off. Three hammers are employed, all of them with two round and somewhat convex faces, though commonly the workman uses only one of the faces: the first, called the catch hammer, is about four inches in diameter, and weighs fifteen or sixteen pounds, and sometimes twenty, tho' few workmen can manage those of this last size: the second, called the shoddering hammer, weighs about twelve pounds, and is about the same diameter: the third, called  
the

the gold hammer, or finishing hammer, weighs ten or eleven pounds, and is near of the same width. The French use four hammers, differing both in size and shape from those of our workmen: they have only one face, being in figure truncated cones: the first has very little convexity, is near five inches in diameter, and weighs fourteen or fifteen pounds: the second is more convex than the first, about an inch narrower, and scarcely half its weight: the third, still more convex, is only about two inches wide, and four or five pounds in weight: the fourth or finishing hammer is near as heavy as the first, but narrower by an inch, and the most convex of all. As these hammers differ so remarkably from ours, I thought proper to insert them, leaving the workmen to judge what advantage one set may have above the other.

A hundred and fifty of the pieces of gold are interlaid with leaves of vellum, three or four inches square, one vellum leaf being placed between every two of the pieces, and about twenty more of the vellum leaves on the outsides; over these is drawn a parchment case, open at both ends, and over this another in a contrary direction, so that the assemblage of gold and vellum leaves is kept tight and close on all sides. The whole is beaten with the heaviest hammer, and every now and then turned upside down, till the gold is stretched to the extent of the vellum; the case being from time to time opened for discovering how the extension goes on, and the packet, at times, bent and rolled as it were between the hands, for procuring sufficient freedom to the gold, or, as the workmen say, to make the gold work. The pieces, taken out from between the vellum leaves, are cut in four with a steel knife; and the six hundred divisions, hence resulting, are interlaid, in the same manner, with pieces of the ox-gut skins, five inches square. The beating being repeated, with

a lighter hammer, till the golden plates have again acquired the extent of the skins, they are a second time divided in four: the instrument used for this division is a piece of cane cut to an edge, the leaves being now so light, that the moisture of the air or breath, condensing on a metalline knife, would occasion them to stick to it. These last divisions being so numerous, that the skins necessary for interposing between them would make the packet too thick to be beaten at once, they are parted into three parcels, which are beaten separately, with the smallest hammer, till they are stretched for the third time to the size of the skins: they are now found to be reduced to the greatest thinness they will admit of, and indeed many of them, before this period, break or fail. The French workmen, according to the minute detail of this process given in the *Encyclopedie*, repeat the division and the beating once more; but as the squares of gold, taken for the first operation, have four times the area of those used among us, the number of leaves from an equal area is the same in both methods, to wit, sixteen from a square inch. In the beating, however simple the process appears to be, a good deal of address is requisite, for applying the hammers so as to extend the metal uniformly from the middle to the sides: one improper blow is apt not only to break the gold leaves, but to cut the skins.

. After the last beating, the leaves are taken up by the end of a cane instrument, and being blown flat on a leather cushion, are cut to a size, one by one, with a square frame of cane made of a proper sharpness, or with a frame of wood edged with cane: they are then fitted into books of twenty five leaves each, the paper of which is well smoothed, and rubbed with red bole to prevent their sticking to it. The French, for sizing the leaves, use only the cane knife; cutting them first straight on one side, fitting them into the book by the straight side, and

then paring off the superfluous parts of the gold about the edges of the book. The size of the French gold leaves is from somewhat less than three inches to three and three quarters square ; that of ours, from three inches to three and three eighths.

The process of gold-beating is considerably influenced by the weather. In wet weather, the skins grow somewhat damp, and in this state make the extension of the gold more tedious : the French are said to dry and press them at every time of using ; with care not to over-dry them, which would render them unfit for further service. Our workmen complain more of frost, which appears to affect the metalline leaves themselves : in frost, a gold leaf cannot easily be blown flat, but breaks, wrinkles, or runs together.

Gold leaf ought to be prepared from the finest gold ; as the admixture of other metals, though in too small a proportion to sensibly affect the colour of the leaf, would dispose it to lose of its beauty in the air. And indeed there is little temptation to the workman to use any other ; the greater hardness of alloyed gold occasioning as much to be lost in point of time and labour, and in the greater number of leaves that break, as can be gained by any quantity of alloy that would not be at once discoverable by the eye. All metals render gold harder and more difficult of extension : even silver, which in this respect seems to alter its quality less than any other metal, produces with gold a mixture sensibly harder than either of them separately, and this hardness is in no art more felt than in the gold-beaters. The French are said to prepare what is called green gold leaf, from a composition of one part of copper and two of silver with eighty of gold ; but this is probably a mistake, for such an admixture gives no greenness to gold, and I have been informed by our workmen, that this kind of leaf is made from the same  
fine

fine gold as the highest gold-coloured sort, the greenish hue being only a superficial teint induced upon the gold in some part of the process: this greenish leaf is little otherwise used than for the gilding of certain books.

But though the gold-beater cannot advantageously diminish the quantity of gold in the leaf by the admixture of any other substance with the gold, yet means have been contrived, for some particular purposes, of saving the precious metal, by producing a kind of leaf called party-gold, whose basis is silver, and which has only a superficial coat of gold upon one side: a thick leaf of silver and a thinner one of gold, laid flat on one another, heated and pressed together, unite and cohere; and being then beaten into fine leaves, as in the foregoing process, the gold, though its quantity is only about one fourth of that of the silver, continues every where to cover it, the extension of the former keeping pace with that of the latter.

*Preparation of gold or gilt wire.*

THERE is very little wire made entirely of gold; and this chiefly for one particular purpose, that of filigree work. What is commonly called gold wire has only an exterior covering of gold, the internal part being silver. A rod of silver, above an inch thick, two feet in length, and weighing about twenty pounds, is coated with gold; and then reduced into wire, by drawing it successively through a number of holes, made in metalline plates, diminishing insensibly in a regular gradation.

The purity of the gold, employed for this use, is a point of the utmost consequence; for on this principally depends the beauty, and durability of the colour, of the laces, brocades, and other commodities prepared from it; and unhappily there is more room for abuse here than in gold leaf, the extension of the metal in this form

being less affected by an addition of alloy. The boasted superiority of the French laces to the generality of those made in England, for which various causes have been falsely assigned, appears to be wholly owing to a difference in the fineness of the gold : our workmen have of late years had finer gold put into their hands than formerly, and the product has been judged not inferior to that of France ; nor is it to be doubted that the English artist, acknowledged not to be wanting in manual dexterity, will, with equal or superior materials, produce an equal or superior commodity. It should seem therefore necessary, for the purposes of so important a manufacture, where so much depends upon the purity of the gold, not only to employ it in the purest state to which it can be brought by the common methods of refining, but even to seek for means of purifying it to a greater degree than any of the common processes are capable of doing : such means the sequel of this essay will afford.

With regard to the silver, which makes the internal body of the wire, its fineness is of less importance. I have been informed by some experienced workmen, that there is an advantage in its being alloyed ; that fine silver, on being nealed in the fire, becomes so soft, as to suffer the golden coat in some measure to sink into it ; and that the admixture of a little copper communicates a sufficient hardness, for preventing this inconvenience. Accordingly the French silver for gilding is said to be alloyed with five or six pennyweight, and ours with twelve pennyweight, of copper, in the pound troy. Some have thought, that this over-softening of the silver might be equally prevented, by using less heat ; and that fine silver, receiving a smoother surface than such as is alloyed, must shew the golden covering to better advantage. How far these presumptions are well founded, or how

far

far the manufacture is affected by the above differences in the quantity of alloy, I cannot take upon me to determine.

The gold is employed in thick leaves, prepared on purpose for this use; which are applied all over the silver rod, and pressed down smooth with a steel burnisher. Several of the gold leaves are laid over one another, according as the gilding is required more or less thick. The smallest proportion allowed by act of parliament is 100 grains of gold to a pound or 5760 grains of silver. The largest proportion, for the best double-gilt wire, as Dr. Halley was informed by the workmen, is 120 grains to a pound; though I am told, that of late the proportion of gold has been increased.

The first part of the drawing process, as well as the preparation and gilding of the silver rod, is performed by the refiner; who uses plates of hardened steel, with a piece of tough iron welded on the back to prevent the steel from breaking. In this back part, the holes are much wider than the corresponding ones in the steel, and of a conical shape; partly, that the rod may not be scratched against the outer edge; and partly, for receiving some bees-wax, which makes the rod pass more freely, and preserves the gold from being rubbed off. The plate being properly secured, one end of the rod, made somewhat smaller than the rest, is pushed through such a hole as will admit it, and laid hold of by strong pincers called clamps, whose chaps are toothed, somewhat like a file, to keep the rod from slipping out by the violence necessary for drawing it: the handles or branches of the clamps are bent upwards, and an oval iron loop put over the curvature, so that the force, which pulls them horizontally by the loop, serves at the same time to press them together: to the loop is fastened a rope, whose  
further

further end goes round a capstan, or upright cylinder, with cross bars, which requires the strength of several men to turn it. The rod, thus drawn through, is well nealed, then passed in the same manner through the next hole, and the nealing and drawing repeated, less and less force sufficing as it diminishes in thickness : when reduced to about the size of a large quill, it is delivered in coils to the wire-drawer.

The remainder of the process requires plates of a different quality ; those of steel, whether in a hard or a soft state, being now found to fret the wire, or to raise a bur upon its surface, and strip off the gold. The plates for this part of the work are brought from Lyons in France : the holes are drilled in them here. They are formed of a metallic mass, whose composition is kept a secret, but whose prevailing ingredient is plainly iron : I have begun an examination of this metal, and shall communicate the result of the experiments in one of the future numbers of this work. There are two sorts of these plates ; one of considerable thickness, for the wire in its larger state ; the other, only about half as thick, for the finer wire, where less force is sufficient in the drawing. There are considerable differences also in the quality of the metal itself, not to be distinguished by the eye, or any otherwise than by repeated trials : such of the thicker plates, as are found good, are valued at a high price. The Lyons plates, though brittle, have sufficient toughness to admit of the holes being beaten up, or contracted, by a few blows of a hammer ; so that when any of them have been widened by a length of wire being drawn through, they are thus reduced again to the proper dimensions for preserving the gradation : the holes, after each beating up, are opened by a long slender instrument, called a point, made of refined steel ; one end of which, to the length of about five inches,



inches, is round, and serves as a handle ; the rest, about twice as long, is square, and tapered to a fine point. The first holes being soonest galled, or so far worn, as to be unfit for bearing further reductions ; the next to them, grown likewise wider, supply their places, and are themselves successively supplied by those which follow ; whence, as each plate is furnished with several more of the small holes than are wanted at first, it continues to afford a complete series after a considerable number of the larger has become unserviceable. Great part of the dexterity of the workman consists in adapting the hole to the wire ; that the wire may not pass so easily, as not to receive sufficient extension, or so difficultly as to be broken in the drawing. For determining this point with greater certainty than could be done from the mere resistance of the wire, he uses a brass plate called a size, on which is measured, by means of notches like steps cut at one end, the increase which a certain length of wire should gain in passing through a fresh hole : if the wire is found to stretch too much or too little, the hole is widened or contracted. As the extension is adjusted by this instrument, there are others for measuring the degree of fineness of the wire itself : slits of different widths, made in thick polished iron rings, serve as gages for this use.

The wire-drawers process begins with nealing the large wire received from the refiner : this is performed by placing it, coiled up, on some lighted charcoal, in a cylindrical cavity, called the pit, made for this purpose, under a chimney, about six inches deep, and throwing more burning charcoal over it : the pit having no aperture at bottom to admit air, the fuel burns languidly, affording only sufficient heat to make the metal red-hot, without endangering its melting. Being then quenched in water for the sake of expedition in cooling it, though the

the metal would doubtless be softened more effectually if suffered to cool leisurely, one end of it is passed through the first hole in the thick plate, and fastened to an upright wooden cylinder six or eight inches in diameter: in the top of the cylinder are fixed two staples, and through these is passed the long arm of a handle, by which the cylinder is turned on its axis by several men. In the continuation of this part of the process, called degrossing, the wire is frequently nealed and quenched, after every hole or every other hole, till it is brought to about the size of the small end of a tobacco-pipe: and in this state it is cut into portions for the fine wire-drawer.

In this last part of the wire-drawing process, nealing is not needful; but it is still as necessary as before to wax the wire at every hole. Much less force being now sufficient for drawing it through the plate, a different instrument is used: a kind of wheel, or circular piece of wood, much wider than the foregoing cylinder, is placed horizontally: in its upper surface are some small holes, at different distances from the axis, and into one or another of these, according to the force required, is occasionally inserted the point of an upright handle, whose upper end is received in a hole made in a cross bar above. From this the wire is wound off upon a smaller cylinder, called a rochet, placed on the spindle of a spinning-wheel; and this last cylinder being fixed on its axis behind the plate, the wire is again drawn through upon the first; and being at length brought to the proper fineness, it is nealed to fit it for the flattening-mill. This nealing is performed in a different manner from the foregoing ones, and with much less heat; for if the wire was now made red hot, it would wholly lose its golden colour, and become black, bluish, or white, as I have often experienced in different parcels of gilt wire. Being wound upon a large hollow  
copper

copper bobin, the bobin is set upright, some lighted charcoal or small-coal placed round it and brought gradually nearer and nearer, and some more small-coal put in the cavity of the bobin; the wire being carefully watched, that as soon as it appears of the proper colour, it may be immediately removed from the heat. This is an operation of great nicety, and is generally performed by the master himself. The wire, though it in good measure retains the springiness which it had acquired in the drawing, and does not prove near so soft as it might be made by a greater heat, is nevertheless found to be sufficiently so for yielding with ease to the flattening mill.

The flattening-mill consists of two rolls, turned in a lathe to perfect roundness, exquisitely polished, placed with their axes parallel one over another, set by screws till their circumferences come almost into contact, and both made to go round by one handle: the lowermost is about ten inches in diameter; the upper commonly little more than two, though some make it considerably larger, and indeed it would be more convenient if made as large, or nearly so, as the lower: their width or thickness is about an inch and a quarter. The wire, unwinding from a bobin, and passing first between the leaves of an old book, pressed by a small weight, which keep it somewhat tight, and then through a narrow slit, in an upright piece of wood called a ketch, which gives notice of any knot or doubling, is directed by means of a small conical hole in a piece of iron, called a guide, to any particular part of the width of the rolls; that if there should be any imperfection or inequality of the surface, the wire may be kept from those parts; and that when one part is soiled by the passage of a length of wire, the wire may be shifted, till the whole width of the rolls is soiled, so as to require being cleaned and polished anew with the

fine powder, called putty, prepared by calcining a mixture of lead and tin : the workmen value the rolls from the number of threads they will receive, that is from the number of places which the wire can thus be shifted to : good rolls will receive forty threads. The wire, flattened between the rolls, is wound again, as it comes through, on a bobin ; which is turned by a wheel, fixed on the axis of one of the rolls, and so proportioned, that the motion of the bobin just keeps pace with that of the rolls.

The rolls, as well as the drawing plates, have been often procured from France ; and it has been thought that the wire received from the French rolls an additional beauty and lustre ; though it does not appear that the French have any durable advantage in this respect above the English, or that the glossiness communicated by either is of any real advantage to the manufacture ; for it quickly goes off. The most important point in their preparation is, the giving them that perfect truth and equability of surface, which the flattening of so fine wire demands. The internal part is formed of iron, and a plate of refined steel is lapped round and welded over the iron : where the two ends of the steel plate meet there is frequently an imperfection, the juncture being generally visible across the face of the roll. In rolls of great width, some curious artists have obviated the inconveniences arising from this cause, by using, instead of a broad plate, a long narrow bar of the steel, and twisting it round the roll in several circumvolutions, that the little inequalities, in hardness and solidity, happening at the junctures, might be in the direction of the ribbon that passes between the rolls, and not transverse to it. In the narrow rolls used for the flattening of wire, a practice of this kind would be very difficult ; but the same end might perhaps be answered, and even more effectually, by casting the steel,  
instead

instead of a straight bar, into the form of a hoop or ring, of a somewhat less diameter than the size of the intended roll ; then forging the hoop, on the round beak and flat of the anvil alternately, to procure it the requisite uniformity of its parts and the due extension ; afterwards placing it in a proper mould, fixing the axis in its due position, and running into the intermediate space some cast iron, which, from its known property of expanding, as it sets or becomes solid, will continue every where to fill the cavity, and irremovably fix itself both to the hoop and to the axis.

*The degree of extension of gold in wire and leaf.*

THE vast extent, to which gold is apparently stretched in the foregoing operations, has induced several persons to make experiments for determining its exact degree by mensuration and weight. In an experiment of Reaumur's, forty-two square inches and three tenths of gold leaf weighed one grain troy ; and Mr. Boyle found that fifty and seven-tenths weighed but a grain. As a cubic inch of fine gold weighs 4902 grains, the thickness of the gold leaf examined by the one was the 207355th, and of that by the other only the 248532nd part of an inch.

Dr. Halley found, that of superfine gilt wire six feet weighed a grain : M. de Reaumur makes about four inches more go to the same weight ; and Mr. Boyle is said, if there be no error in the numbers, to have had gilt wire much finer than any of these. Allowing six feet to make a grain, and the proportion of gold to be that commonly used by our wire-drawers ; the length to which a grain of gold is extended on the wire, comes to be near 352 feet.

In flattening, the wire is extended, according to M. de Reaumur, one seventh part of its length, and to the width

of one ninety-sixth of an inch: in some trials I have seen made by the workmen, the extension in length appeared less, but that in breadth so much greater, that the square extension was at least equal to that assigned by Reaumur. Hence one grain of gold is stretched on the flattened wire, to the length of above 401 feet, to a surface of above 100 square inches, and to the thinness of the 492090th part of an inch.

M. de Reaumur carries the extension of gold to a much greater degree. He says the wire continues gilded when only one part of gold is used to 360 of silver; and that it may be stretched, in flattening, one fourth of its length, and to the width of one forty-eighth of an inch. In this case, a grain of gold must be extended to 2900 feet, or upwards of half a mile, and cover an area of more than 1400 square inches. He computes the thickness of the golden coat, in the thinnest parts of some gilt wire, to be no more than the fourteen millionth part of an inch, so that it is only about a hundredth part of the thickness of gold leaf.

Yet notwithstanding this amazing tenuity, if a piece of the gilt wire be immersed in warm aqua fortis, which will gradually dissolve and eat out the silver, the remaining golden coat will still hang together, and form, while the fluid prevents it from collapsing, a continuous opaque tube. To succeed in this experiment, the aqua fortis must not be very strong, nor the heat great; for then the acid, acting hastily and impetuously upon the silver, would disunite the particles of the gold.

Whether any other metal can be extended to an equal degree is not as yet clear; for as it is the great value of gold which engages the workmen to endeavour as much as possible to stretch it to the largest surface, the same efforts have not been made in regard to the less valuable

metals : to make a fair comparison, trial should be made of extending silver upon the surface of gold in the same manner as gold is extended upon silver. It may be observed also, that as gold is near as heavy again as silver, or contains near double the quantity of matter under an equal volume ; so, if equal weights of the two metals be stretched to equal extents, the silver will be little more than half the thinness of the gold ; and conversely, if silver could be brought to equal tenuity with gold in regard to bulk, it would, in regard to quantity of matter, be near of double extensibility.

*Application of gold leaf and wire on other bodies.*

THERE are various methods of applying the gold, thus extended, to cover the surface of other bodies. For laces and brocades, the flatted gilt wire is spun on threads of yellow silk approaching as near as may be to the colour of gold itself. The wire, winding off from a bobin, twists about the thread, as it spins round ; and, by means of curious machinery, too complex to be described here, a number of threads is thus twisted at once by the turning of one wheel. The principal art consists, in so regulating the motion, that the several circumvolutions of the flatted wire on each thread may just touch one another, and form, as it were, one continued covering.

It is said that, at Milan, there is made a sort of flatted wire gilt only on one side, which is wound upon the thread, so that only the gilt side appears ; and that the preparation of this wire is kept a secret, and has been attempted in other places with little success. There is also a gilt copper wire, made in the same manner as the gilt silver : Savary observes, that this kind of wire, called false gold, is prepared chiefly at Nuremberg ; and that the ordinances of France require it to be spun, for its  
distinction.

distinction from the gilt silver, on flaxen or hempen threads. One of our writers takes notice, that the Chinese, instead of flatted gilt wire, use slips of gilt paper, which they both interweave in their stuffs, and twist upon silk threads: this practice he inconsiderately proposes as a hint to the British weaver. Whatever be the pretended beauty of the stuffs of this kind of manufacture, it is obvious that they must want durability: the Chinese themselves, according to Du Halde's account, sensible of this imperfection, scarcely use them any otherwise, than in tapestries, and such other ornaments, as are not intended to be much worn, or exposed to moisture.

Paper, wood, and other like subjects, are gilded, by spreading upon them some adhesive substances, and when almost dry, so as but just to make the gold stick, applying gold or gilt leaf, and pressing it down with a bunch of cotton, or the bottom of a hare's foot: when grown thoroughly dry, the superfluous or loose gold is wiped off, and the fixed golden coat burnished with a dog's tooth, or with a smooth piece of agate or pebble. Different kinds of adhesive matters are employed for this use: where resistance to rain or moisture is required, oil paints; in most other cases, a size, made from cuttings of parchment or white leather, by boiling them in water.

The composition commonly used for oil gilding consists of yellow ochre, finely powdered, and a suitable quantity of drying oil, ground together till they unite into an uniform mixture, of such a consistence, that it may be freely laid on with the pencil, without spreading beyond the part on which it is applied, and that it may settle smooth with a glossy surface.

For gilding on wood, &c. with what is called water-size, the parchment or leather size above-mentioned is mixed with whiting, and several layers of the mixture  
spread



spread upon the piece, one after another is dry, so as to cover the grain of the wood, and the imperfections left by the tool, and form a perfectly smooth surface for applying the gold upon : over this is commonly spread some of the same size mixed with yellow ochre. These compositions do not well admit of the gold being burnished ; and therefore, where burnished gilding is required, another mixture, called gold-size, is either laid above these, or applied on the wood at first. The gold-size is composed of tobacco-pipe clay, or bolar earths, ground with a smaller proportion of ruddle and black lead, and tempered with a little tallow and oil olive. In these points there is little uniformity among the workmen, the same end being obtainable by different means, among which we cannot perhaps distinguish any superiority in the effect of one to that of another, and of which fancy or prejudice have often chosen the more compounded in preference to the more simple. The principal caution, in regard to the gold-size, seems to be, to use no more of the unctuous materials than is necessary for procuring the due consistence ; and to make a trial of the preparation previous to its being employed in any work of consequence.

For some purposes, the gold is used in powder, which, from its being kept in shells, is called shell gold. This is prepared by grinding gold leaves, or gold-beaters fragments, with a little honey ; and afterwards separating the honey from the powdered gold by means of water. Gold may be reduced also, by dissolving it in mercury, and evaporating the mercury in the fire, or by dissolving it in aqua regis, and precipitating with certain additions, of which hereafter, into a powder, more subtle than can easily be obtained by mechanical comminution.

Gilt

Gilt letters or figures on paper may be formed of shell gold, tempered with gum water : or the characters may be drawn with a milky solution of gum ammoniacum, made in water, and gold leaf applied upon them when almost dry : if they have become quite dry, they may again be sufficiently moistened for receiving the gold by breathing on them. For raised letters, such as are seen in some ancient manuscripts, whiting, yellow ochre, or other earthy powders, are tempered with strong gum water, and the letters formed of this composition, by a pen, or more commodiously, by means of a type or stamp, previously oiled, as hinted in a pamphlet on drawing and painting in water-colours, published in 1731 ; when dried to a due degree of tenacity, the gold leaf is laid on. If the characters are formed of hard bodies, as powdered glass or crystal, they may be covered with a burnished golden coat, by carefully rubbing them with a piece of solid gold.

On the covers of books, the gildings are depressed beneath the surface, and cemented with whites of eggs. The part being rubbed with this liquid, the gold leaf is applied all over it, and the letters or figures made afterwards by heated stamps or rollers, which, at the same time that they form the cavities, press down and fix the gold in them ; while the gold, on the prominent or smooth surface, adheres so loosely as to be easily wiped off.

In the posthumous papers of Mr. Hooke, a method is described of gilding live craw-fish, carps, &c. without injuring the fish. The cement for this purpose is prepared, by putting some Burgundy pitch into a new earthen pot, and warming the vessel till it receives so much of the pitch as will stick round it ; then strewing some finely powdered amber over the pitch when growing cold, adding

ing a mixture of three pounds of linseed oil, and one of oil of turpentine, covering the vessel, and boiling them for an hour over a gentle fire, and grinding the mixture, as it is wanted, with so much pumice stone in fine powder as will reduce it to the consistence of paint. The fish being wiped dry, the mixture is spread upon it, and the gold leaf being then laid on, and gently pressed down, the fish may be immediately put into water again without any danger of the gold coming off, for the matter quickly grows firm in water. As the qualities of this cement excellently fit it for some other purposes, it was thought worth while to insert the whole process.

Drinking-glasses, gilt on the edges, have of late been much admired: the best of these are brought from Germany; those hitherto made in England, though equal in beauty to the foreign, being greatly inferior in the durability of the gilding. It is supposed that the German glasses are gilt by fire: and it is certain that gold leaf may be made to adhere firmly to glass softened by heat, and that the effect may be promoted by the interposition of some vitrescent bodies more fusible than the glass itself: a piece of glass pipe being moistened with a weak solution of borax, then covered with gold leaf, dried, and heated to a full red heat, the gold was found cemented more strongly than that on the German glasses, so as scarce at all to be scraped off with a knife; though in some parts it appeared specky or full of small holes, probably from want of sufficient address in the application of it. But how firmly soever the gold may be thus cemented, it would be very difficult to gild the edges of a glass in this method without damaging the rest; and a careful examination of some of the German glasses shewed pretty plainly that the gold had been fixed on them by other means. The glasses had evidently been ground and polished; yet

the polish even of the part under the gold had not suffered any injury, which it doubtless would have done from a degree of fire sufficient to soften its surface, or from any vitreous intermedium melted to it. The gold could be scraped off pretty easily with a knife; and by steeping for a little time in heated spirit of wine or oil, particularly in the latter, it became more easily separable. One side being thus cleared from the gold, there appeared a smear upon the glass under it; and this being cleaned off, there appeared a like smeariness between the gold and the glass on the opposite side; whereas, on viewing in the same manner the glass which I had gilt by fire, the surface of the gold next to it looked remarkably bright, without the least cloudiness upon the glass. From these observations it may be presumed, that the gold is cemented to the German glasses on the same principle with the foregoing gildings; and that the only secret consists in finding a matter, which will adhere to glass, so as not to be easily rubbed off. I have tried mastich and some other resinous bodies rubbed warm upon the glass, and several spirituous varnishes; but all of them were attended with some inconveniencies, particularly with the grand one of not adhering sufficiently to the glass. I recommend to the trial of the artists concerned in this affair the harder oil varnishes; and shall myself prosecute the enquiry, and when successful, communicate the result.

#### S E C T. IV.

##### *Of the effects of Fire on gold.*

##### *I. Of the melting of gold.*

**G**OLD melts in a low white heat, and, when in fusion, appears on the surface of a luminous bluish green colour. Though its expansion by small degrees of heat, as from freezing to boiling water, is less than that

that of most of the other metals, yet in fusion it seems to expand more than any of the others; rising up with a more convex or elevated surface, as it becomes fluid; and subsiding, and growing more concave or depressed, as it sets again or returns to solidity. From this property it follows, that gold is less fit for receiving sharp and perfect figures when cast into moulds, than silver, copper, lead, or tin, which do not shrink so much, and far less so than iron or bismuth, which expand in their passage from a fluid to a solid state.

The workmen, for the melting of gold, chuse generally a black lead crucible, on account of its being smoother than the Hessian or other common sorts, and consequently less apt to retain any particles of the costly metal: it is likewise much less liable to crack, may be used for several fusions, and does not require the precautions necessary to be observed where the others are employed.

When the gold is divided into small parts, as filings, though all the particles be brought to perfect fluidity, they do not easily reunite into one mass, many of them continuing frequently in distinct drops. This repugnance is judged to proceed from small atoms of dust, or other extraneous matters, adhering to the surfaces of the particles, and preventing their close contact: the addition of certain fusible saline substances, which dissolve and vitrefy earthy bodies in the fire, is found to remove the impediment, and to collect and unite the gold however divided. The use of fluxes is absolutely necessary in these circumstances; and from their apparent utility here, it has been thought that they were needful in other cases, and hence they are often employed where they seem to be little wanted.

Borax, one of the most powerful dissolvents of earthy matters, is, in this respect, one of the best fluxes for gold; but the gold melted with it, however fine, is commonly observed to have its colour made somewhat paler. From what cause this slight diminution of the colour proceeds, I have not been able to discover: nor do the workmen find the diminution considerable enough to prevent their using borax more generally than any other kind of flux. Nitre, added to the borax, prevents this effect; and gold previously made pale by borax has its colour restored by melting it with an addition of nitre: hence this salt is usefully employed where the gold is designed for the high coloured sort of leaf, for gilding, or other purposes where the high colour of the metal is a principal object. When gold is alloyed with copper, and the full proportion of the copper is to be preserved, nitre is never to be used, the base metals being scorified or destroyed by it: in this case it will be advisable to add to the borax a little charcoal in fine powder, which will preserve the copper from being scorified by the heat.

There is another material point, in melting gold, the preservation of its malleability; which is very liable to be injured, either from an excess, or deficiency, or too sudden an abatement of the heat, occasioning an undue arrangement of its parts at the time of its becoming solid. When the gold is made excessively hot, and the mould, into which it is to be poured, is warmed but little or not at all, the metal almost always contracts a degree of hardness and rigidity; whereas by duly proportioning the heat of the mould to that of the metal, its softness and toughness may generally be secured. The gold-beaters, to whom these qualities are of more importance than in any other art, heat the mould, as already observed,

observed, till the tallow, which it is rubbed with, runs and smokes, without taking flame ; and pour out the gold as soon as its surface appears of a bright green colour : the clearness of the colour serves them as a mark both of the gold being of a proper degree of heat, and of its being fine. Those who work in alloyed gold judge also from the appearance of the surface, whether the metal is of such a heat, or such a disposition, as to prove tough or eager when cold ; taught, by use, marks which cannot easily be described. It is supposed by some, that gently shaking or striking the crucible, so as to communicate a kind of undulatory motion to the fluid metal just before it is poured out, contributes to its toughness.

It is a general opinion among metallurgic writers, that fine gold, in fusion, is made brittle by the contact of vegetable coals not thoroughly burnt, or by their fume ; and what is pretty singular, that gold alloyed with copper is not so subject to receive this injury. But it is probable that the brittleness, ascribed to this cause, depended rather upon others : for the gold-beaters, who leave their crucible open, do not find, that the toughness of the gold is at all diminished, either by the vapour of the charcoal, or by a coal in substance falling in ; though, if any such diminution happened, it could not be supposed to escape their notice. There appears to be little danger to the malleability of gold from any kind of fumes but metallic ones.

When gold is made brittle by a small admixture of base metals, or by their fumes, its malleability may be restored by melting it with a little nitre, which scorifies and dissolves all the other metals except silver and platinum. The nitre should be thrown upon the gold just as it is going to melt ; and the metal poured out as soon as it flows thin. A long continuance of the fusion is apt

to destroy the effect of the nitre, and render the gold as brittle as it was before : for so much of the nitre, as has acted upon the base admixtures of the gold, is changed by that action into an alkaline salt ; and the slightest access of any inflammable matter is sufficient to revive the scorified metallic particles from the alkali, and render them again miscible with the gold. Corrosive mercury-sublimate, thrown by a little at a time upon gold in fusion, with care to avoid its noxious fumes, answers the same end with nitre, and is commonly preferred to it by the workmen : on what foundation the effect of sublimate depends, will appear hereafter.

II. *Of the alterations said to be producible in gold by fire.*

The greatest degrees of artificial fire, continued for a length of time, have not been observed to make any alteration in gold. Gasto Claveus, in an apology for the alchemists, printed in the second volume of the *Theatrum chymicum*, relates, that he put an ounce of pure gold, in an earthen vessel, into that part of a glass-house furnace where the glass is kept constantly melted, and continued it there in fusion for two months together ; and Kunckel mentions a like experiment, made in the glass furnace of the duke of Holstia, in which the gold was exposed to the fire for almost thirty weeks. These vehement and continued degrees of heat it was found to support, without suffering any sensible alteration of its quality, or diminution of its weight ; whereas the other metals, platinum and silver excepted, are soon deprived by fire of their metallic aspect, and either dissipated in fumes, or changed to an earthy or glassy form.

What common fire effects in the base metals has been said to be effected in gold by the more intense heat collected in the focus of large burning-glasses. Mr. Hom-



berg reports, in the memoirs of the French academy for the year 1702, that he exposed gold, on a piece of charcoal, to a burning lens, about thirty-three inches in diameter, whose activity was further increased by the interposition of a smaller lens placed at a proper distance for contracting the focus into a less compass: that this vehement heat produced a powdery matter on the surface of the gold, which, gathering together, formed a vitreous drop in the middle, and then run off to the sides; that the surface, now bright, became again gradually covered with a like dust, which in like manner vitrified and run off; that fresh drops of glass continued to be thus produced; and that at the same time great part of the gold evaporated in fumes.

This experiment, as Cramer very justly remarks, does not seem to have been made with sufficient care, or carried to a sufficient length, to warrant the consequences that have been drawn from it. The purity of the gold ought to have been scrupulously examined, which it does not appear to have been at all; and such part of it as remained unaltered after the operation, ought to have been further submitted to the same treatment; for if any part of the gold was really changed, the whole would doubtless have suffered the same change from a continuance of the same cause. The author, sensible of this, says indeed, that if the gold be exposed long to the heat, it will at length be totally vitrified or evaporated: but he does not affirm that this actually did happen, and seems only to have judged from the first appearances that it would happen. To attempt the revival of the glass into gold again, which Cramer and Macquer require for the satisfactory proof of its having been produced from gold, was not perhaps to be expected from him; since, according to his theory, the glass consisted only of the earthy part of  
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the gold, the specifying principles of the metal being supposed to have evaporated in the intense heat: yet, if he really believed that it proceeded from the gold at all, it is extremely strange, that so curious a chemist should pass over a product so extraordinary, and so interesting to his favourite pursuits, without the least examination, and even neglect to repeat and verify the singular experiment by which it was obtained; especially as he had all possible opportunities of prosecuting the enquiry, the apparatus being at his command, and the materials provided for him by royal munificence. From one of his subsequent papers published in the same memoirs for the year 1707, it appears, that this vitrification of the gold was called in question by one who had been witness to the experiment; who took notice that some ashes, flying off from the charcoal on which the gold was placed, fell from time to time upon the surface of the metal; and hence judged, that the little quantity of glass obtained was no other than a vitrification of these ashes. An objection so well founded required surely a repetition of the process, and a more attentive observation of the phenomena; but the author answers only by another experiment, which appears also to be single in its kind, that when silver was exposed on a piece of charcoal in the same manner, no vitrification happened; as if the ashes could not be casually accumulated on the metal, so as to produce a sensible vitrification, in one instance, without being so in another.

I have been the more particular in the account of this experiment, because it has been relied on by many as an indubitable proof of gold being alterable in its nature; and because a due attention to what the author himself has thought fit to communicate, shews it to be at best too imperfect for any stress at all to be laid upon it. The want of a proper apparatus here is an insuperable obstacle

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to my repeating the experiment: but it is said that others have repeated it, and found strong reasons to believe that Homberg was deceived. M. Macquer relates, that several persons have exposed gold to the focus of the same burning lens, and even of others still stronger, without ever being able to vitrefy it: and that, though the gold did indeed decrease in weight, yet the diminution appeared to happen, not from any of the principles of the metal being separated, but from minute globules of it forced off in substance; many of which were caught on a piece of paper placed underneath, and found to be perfect gold unchanged. It is probable, that these globules were forced off from the liquefied gold, not by the action of the heat upon the metal itself, but upon its vessel or support; for all the common vessels, or other substances that can be employed for this purpose, on being exposed suddenly to a great degree even of artificial fire, crackle or fume, and throw up a part of their contents.

The earlier chemists, finding gold to be proof against the vehemence of their fires, thought milder means might be more effectual, for loosening the close union of its component parts, and producing changes in it similar to those producible in the base metals. Accordingly they exposed it, for several weeks or months together, to the immediate action of a gentle fire or flame not much greater than that in which lead melts: by this method it is said to have been notably altered in its properties, and to have assumed several new ones: Kunckel, in his *Laboratorium Chymicum*, affirms that he has succeeded in this experiment, and says that the gold swells up into a spongy substance, like iron treated in the same manner. The obscure and imperfect accounts given of the process prevent our being able to repeat it so as to determine with

certainty its true effect : but there appears as little reason to believe, in this as in the other case, that the gold suffered any permanent change. The gold is required to be previously prepared : if this preparation consists, as it most probably does, in combining it with any other kind of matter that will abide with it in the fire, and reducing it into subtile powder, a heat of no long continuance will occasion a remarkable alteration in its aspect, though its other properties remain entire. If gold leaf be divided by grinding it with an admixture of earthy powders, as calcined hartshorn or chalk, or with saline ones of the more fixed and less fusible kind, as vitriolated tartar, and exposed, for sixteen or twenty hours, to a moderate heat, scarce sufficient to keep the vessel red hot; the gold wholly loses its metallic brightness, and changes its yellow colour to a red or purple. On separating, by means of water or acids, the soluble salt or earth, the remaining golden powder recovers by simple fusion its proper metallic form ; a strong heat divesting it of those superficial appearances which a weaker one had induced.

## S E C T. V.

### *Of the Mixture of gold with other metals.*

**T**HE repugnancy or contrariety, which obtains in sundry instances, between different metallic bodies made fluid by fire, and which is no less strongly marked than that betwixt oil and water, is no where observed in regard to gold ; this metal uniting readily with all the other known metallic bodies, and seeming to have a strong, though not equal, affinity to them all.

#### I. *Of*

I. *Of the mixture of gold with mercury: Gold powder, water-gilding, &c.*

MERCURY, in the greatest cold that obtains in our atmosphere, adheres readily to gold, totally conceals its colour, communicating a silver whiteness to every part it touches, and by degrees penetrates and dissolves it. Some of the chemists speak of an animation of mercury, by which its activity on gold is greatly increased; and Mr. Boyle relates, that he had himself prepared mercury, so as to dissolve half or even equal its weight of gold leaf, and to produce, during the dissolution, a sensible heat, sometimes considerable enough to be offensive to the hand: but an enquiry into this point belongs rather to the history of mercury than of gold.

In order to obtain a smooth amalgam, or uniform mixture, of gold and common mercury, the union is expedited, by reducing the gold into thin plates or grains; which are heated red hot, and in this state thrown into as much mercury, as will cover them, previously heated in another crucible, till it begins to smoke: on stirring them together with an iron rod, the gold soon dissolves and disappears. If the amalgam is designed for any nice uses, it should be cleansed, from any filth it may have contracted, by grinding it in a glass, stone, or wooden mortar, with some common salt and water, and occasionally renewing the water, till the amalgam ceases to discolour it, and appears of a pure vivid brightness.

When the proportion of mercury is large, so that the mixture continues fluid when cold, a considerable part may be separated by pressing it through soft leather, as the thicker kind of wash-leather or doe-skin: so much of the quicksilver may be squeezed out, as to leave a butyraceous or consistent mass, containing little more than one

part of mercury to two of gold, but still of a silver whiteness, as if there was no gold in it. The consistent amalgam grows soft on being warmed or worked between the fingers, and hardens on lying in the cold, whence it has been proposed as a proper material for making seals from impressions in wax: the amalgam of gold appears however to have no advantage in this respect above those of the inferior metals, as is well known to some impostors, who have sold amalgams of base metals, for this use, as curious preparations of gold. The mercury, strained off from the amalgam, should be reserved for the like purposes again, as the leather, though no visible imperfection happens in it, may have its pores so far dilated by the pressure, as to suffer some small particles of the gold to pass through with the mercury: this may be discovered by evaporating a little of the quicksilver over the fire, which in this case will leave a yellow spot on the bottom of the vessel.

Mercury, one of the most volatile of the metallic bodies, is expelled from gold by a fire not sufficient to make the mixt red hot. If the amalgam is exposed hastily to this degree of heat, it is apt to swell up and leap about, and part of it to be thrown over the vessel: if the fire is gentle at first, and increased by degrees, the mercury exhales quietly. The impalpable atoms, into which the gold had been divided by its dissolution in the quicksilver, continue disunited after the quicksilver has exhaled; provided due care is taken in the regulation of the fire, and in stirring and rubbing the matter, towards the end of the process, so as to expose it equally to the heat, and prevent its running into lumps. By this method a powder of gold may be obtained, much finer than that prepared by the grinding of gold leaf, and which has likewise this advantage, for the purposes of painting, that  
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it admits better of being burnished. It is obvious, that for uses of this kind, the mercury ought to be pure, as well as the gold : for the lead or other base metals, with which mercury is too frequently impregnated, will be left behind, and discolour the gold.

If an amalgam of gold be spread upon copper, and the mercury evaporated by fire, the gold will remain fixed all over the surface of the metal, and thus afford a firm and durable gilding. The workmen rarely chuse pure copper for gilding upon in this manner, but generally mix with it about a seventh part of brass, that is, of a composition of copper and zinc : they suppose that this addition renders the copper less porous, and makes a less quantity of gold to serve : whatever there may be in this notion, the brass is plainly of use on another account, to facilitate the adhesion of the mercury ; for mercury unites exceeding difficultly with pure copper, and much more easily, as I have often found in experiments of amalgamation, with copper divided by zinc.

The piece to be gilt being well cleaned, some mercury, shaken with a little aqua fortis, is spread upon it, till the surface appears all over white as silver : being then heated, and re-touched in those parts which have escaped the mixture, the amalgam of gold is laid on : the heat, softening the amalgam, makes it spread the more freely ; and the intervention of the mercury and aqua fortis occasions it to adhere more uniformly. The piece, thus covered with the amalgam, is placed on a convenient support, over a charcoal fire ; and examined from time to time, as the mercury evaporates, that if any deficiencies appear, they may be supplied with a little more of the amalgam before the process is completed. If a thicker gilding is required, than can result from so much of the amalgam as is applied at once, the piece,  
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after the first quantity has left its gold fixed upon the surface, is rubbed afresh with the mixture of mercury and aqua fortis, and more of the amalgam spread upon it : after the evaporation of the mercury from this, another and another quantity may be applied in the same manner. The golden coat, left after these operations, is sometimes of a pale dead colour ; occasioned perhaps, partly, by impurities in the mercury, and partly, by a little of the mercury itself left unevaporated. Whatever be the cause, the workmen find a remedy in rubbing upon the piece, while warm from the fire, (after the loose particles of gold have been wiped off with a clean scratch brush, made of very fine brass wire bound together,) a composition, called gilding wax, which being burnt off, some more of it is rubbed on, and this application repeated till the gold appears of a proper colour. The gilding wax is composed of bees-wax, red ochre or ruddle, verdegris, vitriol or alum, and sometimes other additions: the acid of the salts and the cupreous part of the verdegris seem to be the materials on which the effect of the compound chiefly depends. I have been informed by an ingenious artist, that he has employed for many years a saline composition without wax, and found it to answer extremely well : equal quantities of nitre, sal ammoniac, green vitriol, and verdegris in fine powder, are mixed together, moistened with water, and applied upon the piece ; which is then heated till the mixture smokes, and quenched in urine.

There are two principal inconveniencies in this business : one, that the workmen are exposed to the fumes of the mercury, and generally, sooner or later, have their health greatly impaired by them : the other, the loss of the mercury ; for though part of it is said to be detained in cavities made in the chimney for that purpose, yet the greatest part of it is lost. From some trials I have made



it appeared that both these inconveniencies, particularly the first and most considerable one, might in good measure be avoided, by means of a furnace of a due construction. If the communication of a furnace with its chimney, instead of being over the fire, is made under the grate, the ash-pit door or other apertures beneath the grate closed, and the mouth of the furnace left open; the current of air, which otherwise would have entered beneath, enters now at the top, and passing down through the grate to the chimney, carries with it completely both the vapour of the fuel, and the fumes of such matters as are placed upon it: the back part of the furnace should be raised a little higher above the fire than the fore part, and an iron plate laid over it, that the air may enter only at the front, where the workman stands, who will thus be effectually secured from the fumes, and from being incommoded by the heat, and at the same time have full liberty of introducing, inspecting and removing the work. If such a furnace is made of strong forged (not milled) iron plate, it will be sufficiently durable: the upper end of the chimney may reach about a foot and a half higher than the level of the fire: over this is to be placed a larger tube, leaving an interval of an inch or more all round between it and the chimney, and reaching to the height of ten or twelve feet, the higher the better. The external air, passing up between the chimney and the outer pipe, prevents the latter from being much heated, so that the mercurial fumes will condense against its sides into running quicksilver, which falling down to the bottom, is there caught in a hollow rim formed by turning inwards a portion of the lower part, and conveyed, by a pipe at one side, into a proper receiver.

Mr. Hellot communicates, in the Memoirs of the French academy for the year 1745, a method of making raised figures

figures of gold on works of gold or silver, found among the papers of Mr. du Fay, and of which Mr. du Fay himself had seen several trials. Fine gold in powder (such as results from the parting of gold and silver by aqua fortis, as described hereafter) is directed to be laid in a heap on a levigating stone, a cavity made in the middle of the heap, and half its weight of pure mercury put into the cavity : some of the fetid spirit, obtained from garlick root by distillation in a retort, is then to be added, and the whole immediately mingled and ground with a muller, till the mixture is reduced into an uniform grey powder. The powder is to be ground with lemon juice to the consistence of paint, and applied on the piece previously well cleaned and rubbed over with the same acid juice: the figures drawn with it may be raised to any degree by repeating the application. The piece is exposed to a gentle fire till the mercury is evaporated so as to leave the gold yellow, which is then to be pressed down, and rubbed with the finger and a little sand, which makes it appear solid and brilliant: after this it may be cut and embellished. The author observes, that being of a spongy texture, it is more advisable to cut it with a chisel than to raise it with a graver ; that it has an imperfection of being always pale, and that it would be a desirable thing to find means of giving it colour, as by this method ornaments might be made of exquisite beauty and with great facility. As the paleness appears to proceed from a part of the mercury retained by the gold, I apprehend it might be remedied by the prudent application of a little warm aqua fortis, which dissolving the mercury from the exterior part, would give at least a superficial high colour : if the piece is silver, it must be defended from the aqua fortis by covering it with wax. Instruments or ornaments of gold, stained by mercury, where the gold is connected with substances

substances incapable of bearing fire, may be restored to their colour by the same means.

The foregoing process is given entirely on the authority of the French writer. I have had no experience of it myself, but have seen very elegant figures of gold raised upon silver, on the same principle, by a different procedure. Some cinnabar was ground, not with the distilled spirit, but with the expressed juice of garlick, a fluid remarkably tenacious: this mixture was spread all over the polished silver; and when the first layer was dry, a second, and after this a third was applied. Over these were spread as many layers of another mixture, composed chiefly of asphaltum and linseed oil boiled down to a due consistence. The whole being dried, with a gentle heat, on a kind of wire grate, the figures were traced and cut down to the silver so as to make its surface rough: the incisions were filled with an amalgam of gold, raised to different heights in different parts according to the nature of the design; after which a gentle fire, at the same time that it evaporated the mercury, destroyed the tenacity of the gummy juice, so that the coating, which served to confine the amalgam and as a guide in the application of it, was now easily got off. The gold was then pressed down and embellished as in the former method, and had this advantage, that the surface of the silver under it having been made rough, it adhered more firmly, so as not to be in danger of coming off, as M. du Fay says the gold applied in his way sometimes did. The artist however found the process so troublesome, that though he purchased the receipt for a considerable sum, he has laid the practice aside.

Mercury and amalgams rubbed on iron do not at all adhere to it: there are however means of applying the mercurial gilding on this metal, as well as on copper and silver. If the iron be dipt in a solution of the blue vitriol of copper, or rubbed with the vitriol itself somewhat

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moistened, it becomes immediately covered with a cupreous coat, and now receives the gilding in the same manner as solid copper.

II. *Of the mixture of gold with silver, copper and other metals; the alterations produced by different proportions of different metals, and the effects of strong or continued fire on the mixtures.*

ALL the metals, which melt easier than gold, dissolve it in a less heat than the gold would melt in; and gold, brought into fusion, dissolves in like manner those which are more difficultly fusible. It is particularly disposed to unite with iron, of which, if the iron be pure, it dissolves twice or thrice its own weight in a degree of heat very far less than that in which iron melts: if stirred in fusion with an iron rod, it corrodes a part of the iron, and a large portion of the gold adheres to the instrument: hence Cramer, Schlutter, and other writers on assaying, prudently caution against the use of an iron rod for the stirring of melted gold. In virtue of this property, gold proves an excellent folder for the finer kinds of iron and steel instruments: a small thin plate of gold being wrapped round the parts to be joined, the gold is soon made to melt by a blow-pipe, and strongly unites the pieces together, without any injury to the instrument, however delicate.

On copper, its apparent action is much less considerable; yet, when once it is united with this metal, the increase of fusibility is more strongly marked, mixtures of gold with a little copper being found to melt with less heat than pure gold itself. Hence mixtures of this kind serve as folders for gold: two pieces of fine gold are foldered by gold that has a small admixture of copper; and gold alloyed with copper is foldered by such as is alloyed with  
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more copper : the workmen add a little silver as well as copper, and vary the proportions of the two to one another, so as to make the colour of the solder correspond, as nearly as may be, to that of the piece : copper alone, in the quantity requisite to procure the due fusibility, would incline the mass too much to its own colour.

SILVER, mixed with gold, dilutes its yellow colour more or less according to its quantity. One twentieth or less of silver renders gold very sensibly paler ; and the addition of a twentieth more makes it sensibly paler than the former proportion : but when the silver is increased to a tenth or an eighth of the gold, so small differences in the quantity scarce occasion sensible variations in the colour, and still less so when the silver exceeds the gold ; a little gold not near so much affecting the colour of silver, as a little silver does that of gold. All the mixtures are very malleable, though somewhat harder, firmer, and more sonorous, than either of the metals separately : in this respect, as in the colour, a little silver affects gold more than a little gold does silver.

Copper, in small quantity, renders the gold somewhat harder than silver does, and somewhat heightens the colour, by superadding its own reddishness to the gold yellow ; but if the quantity of copper is considerable, the coppery hue prevails : a little gold mixed with copper makes no remarkable alteration either in its colour or ductility. The high colour which a small proportion of copper communicates to gold, has been observed in different circumstances, and given rise to sundry processes for the exaltation of the colour of the noble metal. Some recommend for this purpose the superficial application of verdegris, blue vitriol, or other preparations of copper ; which indeed are often used by the workmen, but whose

effect seems to be, not the heightening of the colour of the metal itself, but the removal of the superficial tarnish or discoloration which alloyed gold is apt to receive from the fire; and this effect appears to proceed, not from the copper, but from the acid which these preparations contain. Others, for communicating a high colour to the whole mass, direct the gold to be melted with three or four times its weight of the highest coloured copper, the mixture to be granulated or flatted into plates, then boiled in weak aqua fortis, in order to separate as much of the copper as the acid will extract, the remaining gold to be melted with fresh copper, and this process repeated several times. It is apprehended, that by this method only a small portion of the copper will be left in the gold, and that this little will be so intimately commixed with it as to resist the action of acids and of the air; and that the gold will thus receive the admired colour, without being made much more liable to tarnish, or to change its colour on washing or boiling, than fine gold.

Platina, next to the two foregoing metals, injures the malleability of gold the least. Mixtures of gold with one twentieth of its weight of platina I have drawn into moderately fine wire: mixtures of it with one fourth its weight were forged into pretty thin plates: and a mixture of equal parts (which is as large a proportion of platina as can be easily united with gold) was indeed brittle, but bore several strokes, and stretched considerably under the hammer, before it began to crack about the edges. With regard to the colour, small proportions of the platina, as one sixtieth, make little alteration: in larger proportions, as one twelfth, it communicates, not its own whiteness, but a particular and remarkable dull hue, the compound approaching more to the colour of bad copper than of gold:

gold: in the quantity of one fourth and upwards, it gives a dull whitishness.

Iron or steel, in very small proportion, render gold hard and eager, and on increasing the quantity of the iron, the mixt continues brittle: some of these mixtures are of such a degree of hardness and closeness, as adapts them for receiving a fine edge, and it is said that they have been formed into razors. The colour of the gold is made pale by a small quantity of the iron: equal parts of the two form a grey mass: if the quantity of the iron is three or four times greater than that of the gold, the mixt proves of a white colour, approaching to that of silver.

All the rest of the metallic bodies give paleness, dullness, and brittleness, in different degrees, some more than others in the same quantities. Of tin and lead the most minute proportions, even the vapours which rise from them in the fire, though not sufficient to add to the gold any weight sensible in the tenderest balance, make it so brittle that it flies in pieces under the hammer; though gold, contrariwise, mixed with a small proportion of the lead or tin, does not appear to injure their malleability. Something of the same kind seems to happen in the mixtures of gold with the metals which of themselves are brittle, as zinc, bismuth, and regulus of antimony; a small proportion of these metals rendering gold extremely brittle, whereas, when the brittle metal is in large proportion, its fragility is diminished by the gold: thus Mr. Hellot observes, in a paper on zinc published in the French memoirs for the year 1735, that a mixture of three parts of zinc and one of gold does not break so easily as a mixture of equal parts of the two. Some of these mixtures, particularly one of equal parts of gold and zinc, bear a fine polish, and probably, as the above mentioned author takes notice, would

be excellent for making specula, being less subject to tarnish in the air than the compositions of which copper is the basis.

It is supposed by many, that gold, melted with other metals, is always diffused equally through their whole volume, insomuch, that the quantity of gold, obtainable from any part of the mixt, shall bear exactly the same proportion to that part, as the whole of the gold does to the whole mass. There appears, however, in many cases, a sensible inequality in the distribution. M. Hellot, in his French translation of Schlutter's German work on the smelting and assaying of ores and metals, gives an account of an experiment which clearly shewed this inequality: a quantity of silver, amounting to upwards of twenty pounds, containing about a fifty-sixth part of gold, was melted in a crucible, and poured into cold water, in order to its being reduced into grains: by dipping at different times an iron ladle into the water, under the stream of metal, he received a part of the first running, a part of the middle, and a part of the last: the three parcels, assayed separately, were all found to differ in their content of gold.

There is a curious experiment of Mr. Homberg's, related in the French memoirs for the year 1713, which, though I have not yet tried it, I shall venture to insert on account of its singularity. Equal parts of gold and silver, melted together and reduced into fine grains, were put into a crucible, with a mixture of about equal parts of decrepitated sea salt and rough nitre under them: the crucible being kept in a small fire, in a wind-furnace, for about a quarter of an hour, and then suffered to cool and broken, the gold was found in one lump at the bottom, and the silver above it in two pieces, with some grains,  
wrapped



wrapped up in the salts, which had not entirely melted : the silver was perfectly pure, and without the least mixture of gold, but the gold retained about a sixth part of silver. He repeated the experiment with different mixtures of the two metals, and found the silver to be always pure from gold, but that the gold retained a little of the silver, except in two instances, in which this also was pure. He observes, that unless the gold and silver are nearly in equal quantities, the separation does not succeed ; and that the only nicety in the process consists in hitting the due point of fusion, for if the fire is too long continued, or the mixt made to flow thin, the two metals, after they have parted from one another, mingle again together.

We have already seen that mercury may be evaporated from gold by a gentle heat : there are some other metallic bodies also, which may be totally dissipated from gold by fire, but with considerable differences in regard to the circumstances of the separation. Arsenic, though of itself very volatile, adheres so strongly to gold as not to be easily expelled : if the mixture is urged hastily with a violent fire, a part of the gold is carried off by the arsenical fumes. Zinc, in open vessels, burns, changes into white flowers, and throws up along with its own fumes a small portion of the gold, which tinges a part of the flowers of a yellowish colour inclining to purple : these flowers do not rise high, part of them forms about the surface of the mass, and when once they are formed, they resist the fire ; so that though the whole of the zinc, by frequent stirring and strong fire, should be thus changed, yet, unless the proportion of gold be large, the noble metal remains divided and interspersed among the flowers. In close vessels, or where the external air has no access, the zinc, by force of fire, may be totally made to sublime : it may be expelled also in an open crucible, by keeping the  
mixt

mixt covered with powdered charcoal, which, so far as it reaches, prevents the above change of the zinc.

The dissipation of regulus of antimony from gold requires, on the contrary, not only an open vessel and free access of air, but the artificial impulse of a blast of air upon the surface : if the fire is vehement, the crucible shallow, and the air strongly impelled, the gold is volatilized by this metal more considerably than by either zinc or arsenic ; but with proper care, the regulus may be blown off without any sensible loss of the gold. Some have proposed regulus of antimony instead of mercury for gilding on copper ; as also on earthen ware and glass, on which the mercurial gilding cannot be applied : the regulus and gold, first melted together, are directed to be ground into fine powder, which being spread upon the piece, the whole is exposed to a strong red heat, so as to evaporate the regulus. The inconveniencies of this method are, that the powder does not of itself adhere to the subject, and can scarce be equably spread, and that part of the gold is wasted : that glass melts in the heat necessary for the exhalation of regulus of antimony, and that copper is liable to be corroded by the regulus, and have its surface rendered uneven.

The base metals in general, which calcine or change to an earthy form in the fire, suffer the same change when mixed with gold, though with some differences in the degree of facility. If gold, mixt with a small proportion of these metals, be kept for a considerable time in fusion, the base metal, gradually scorifying, rises to the surface, no longer miscible with the gold. If the gold is in less quantity, and the fire insufficient to bring the mass into fusion, the whole mixt loses by degrees its metallic aspect, and the gold remains intermingled among the calx of the base metal, in a more attenuated state than it can perhaps

be brought to by other means : by long continuance of a moderate fire, the calx acquires more or less of a purple hue, according to the quantity of the gold and the natural colour of the calx of the metal it is mixed with.

Tin, which when calcined by itself is neither vitrescible nor fusible in the fire, and which cannot be perfectly vitrified by the most active substances commonly made use of in this intention, is remarkably affected by the admixture of gold. Dr. Brandt relates, in the transactions of the Swedish academy for the year 1753, that two parts of tin, and three of gold, being melted together, reduced into fine powder, and calcined only to an ash grey colour, the calx melted with ease into a yellow glass, at the bottom of which was found a metallic regulus. I shall examine this curious experiment on another occasion.

Though gold, in the highly attenuated state into which it is thus reduced by calcination with base metals, is by some bodies otherwise acted upon than in its grosser form, as appears from its habitude to tin in the preceding paragraph, and to the marine acid in the following section, it is by no means divested of its metallic properties, or changed into a calx. Mercury, which does not dissolve metallic calces, any more than unmetallic earths and stones, on being triturated with the compound powder, imbibes the gold ; and on this foundation, gold, blended with the base metals, may in some cases be advantageously extracted from them.

If mixtures of gold and lead be continued in a fire sufficient to keep them in perfect fusion, the lead, calcining and rising to the surface, changes into a fluid scoria, easily separable from the gold by means to be described hereafter. Bismuth also scorifies and separates in the same manner ; and both these metals, promoting the scorifica-

tion, or fusion of the calces, of the other base metallic bodies, promote their separation from gold in the fire.

## S E C T. VI.

*Of the action of acid and sulphureous bodies on gold; various solutions of it, and their properties.*

### I. *Gold with the nitrous acid.*

**T**HE acid spirit extracted from nitre, whether in its concentrated state, or in the more dilute one, in which it is commonly called aqua fortis, has not been found to have any action on pure gold. Hence gold is freed, by this acid, from silver, copper, lead, zinc, mercury, and such other metallic bodies as the acid dissolves: but that this separation may succeed, the quantity of the inferiour metal must be considerably greater than that of the gold, for otherwise its particles will be enveloped by the gold so as to be entirely defended from the acid.

When nitre in substance is mixed with certain bodies containing the vitriolic acid, as calcined vitriol, and the mixture made red hot, the acid of the nitre is extricated in yellowish red fumes. If the impure gold is interlaid with such a mixture, and exposed to the fire along with it, in a close vessel that the fumes may be confined; the base metal will be in part corroded, though its quantity is far less than would be acted upon by the acid in its liquid state, but in this case the acid penetrates only a little way into the mass. Hence, for the purification of gold by this method, the operation must be two or three times repeated, the metal being each time melted and reduced into thin plates, that fresh surfaces may be exposed to the fumes: and in the process by aqua fortis, if the base metal does not amount to a certain quantity, more base metal must be added. The method of conducting

ducting the operations will be described in the eighth and ninth Sections.

As pure gold has been always found to resist the nitrous acid, and as gold divided by silver or other metals has not been observed to be acted upon by that acid in the common processes of assaying or refining; it has been universally laid down as an axiom, that the pure nitrous acid can in no case have any action on gold, and that, in whatever manner it be applied to mixtures of gold with other metals, it can dissolve only the inferior metal, and will always leave behind the full quantity of gold which the mixt contained. Here it may be observed, once for all, that as the mutual relations of bodies are multifariously modified by the circumstances in which the subjects are applied to one another, sundry bodies discovering strong repugnancies in some circumstances, and strong affinities in others; we never can infer, from the constancy and uniformity of the action or inaction of two bodies on each other in all the circumstances in which they have been applied, that their relations will be the same in any other circumstances; and consequently, unless all possible means of application were known and experienced, no axiom, in regard to the chemical affections of bodies, ought to be admitted as universal. Though the assayer and refiner depend upon the absolute indissolubility of gold by the nitrous acid, yet there are circumstances, in which gold is dissolved by this acid in considerable quantity.

This curious and important discovery was made by Dr. Brandt, and published in the Swedish transactions for the year 1748. In order to part a mixture of gold and silver, amounting to about fifteen pounds, in which the proportion of the silver to the gold was as sixteen to three (including with the silver a little copper which it contained)

he boiled it with fresh portions of stronger and stronger aqua fortis, in a glass body, to which was fitted a head and recipient for collecting the acid vapours that arose : this method should seem at first to be a notable improvement on the common process, in which the vapours, that issue plentifully during the action of the acid, exhale and are lost. Nearly all the silver and copper being dissolved, and the solution poured off from the gold, the next portion of aqua fortis was boiled down till the matter at the bottom looked like a dry salt ; which being judged to have been so much deprived of the acid, that there was not enough left to render the little remaining silver dissoluble by water, he added more aqua fortis ; which, after boiling for some time, appeared yellow, and was poured off into a separate glass, its yellowness being looked upon as a mark of its having become exceeding strong by the loss of its watery parts in the process.

This yellow aqua fortis he used afterwards for dissolving some silver, when, to his astonishment, a considerable quantity of gold was found at the bottom of the glass, though the silver had before been very carefully purified from gold. This experiment was many times repeated, in the presence of several assayers, and at a meeting of the Swedish academy, and always with the same event ; pure silver, which gave no mark of gold with common aqua fortis, precipitating from the above yellow aqua fortis a spongy lump of gold. In keeping, a part of the gold separated spontaneously, in form of a brown powder : after it had been long kept, and deposited much of its gold, it was found on an assay to contain more gold than silver, in the proportion of 19 to 12 : in this state, a quantity of it sufficient to dissolve four parts of silver yielded during the dissolution one part of gold ; so that the nitrous acid is capable of dissolving above one fourth part as much gold

as it is of silver. The nitrous spirit made use of in this operation had been prepared from pure nitre, and the experiment itself affords a convincing proof, that it was by the pure nitrous acid that the gold was dissolved; for if the dissolution of this metal had been produced, as might be suspected, by means of an admixture of marine acid, the menstruum could not, in the above method of application, have dissolved the silver.

The foregoing process differs from that commonly followed for the parting of gold and silver, in the vessel being close so as to exclude the external air, and in the heat being continued at last till the matter became dry, so that as the watery parts of aqua fortis rise first in distillation, the acid must in this case have been greatly concentrated. Though the applying a head upon the vessel may seem to be a very immaterial circumstance in regard to the dissolution of the metal, it is perhaps one of the most essential, for both dissolution and precipitation are in many cases remarkably influenced by the admission or exclusion of air: after the gold has been dissolved, if the vessel be well shaken, so that air may be copiously introduced and mingled with the liquor, the gold, as Mr. Scheffer observes, falls quickly to the bottom.

The importance of this experiment, in the way of caution to those concerned in the parting of gold and silver by aqua fortis, is apparent. It is probable, that gold has been often dissolved in aqua fortis, without being known to be so; and that this was the true cause of the deception of Becher and other chemists, who report that they had seen silver transmuted into gold by dissolution in some particular kinds of aqua fortis. Had Dr. Brandt's solution passed into other hands than his own, it might possibly have been looked upon as another instance of these pretended graduating or transmuting menstruums.

## II. *Gold with the marine acid.*

THE pure acid of sea salt has no action on gold, so long as the gold retains its metallic form; whether the metal be boiled with it in open or in close vessels, or exposed in the fire to its fumes; in which last circumstance, this acid dissolves or corrodes all the other known metallic bodies, except platina. Hence, though there are several metallic bodies, as silver, which the marine acid in its liquid state does not dissolve or extract from gold, yet gold may be purified from those metals by the fumes of this as well as of the nitrous acid. On this foundation, the brittleness, which a small admixture of lead or tin produces in gold, is remedied, by repeatedly injecting upon it in fusion a little corrosive mercury-sublimate; the marine acid of the sublimate uniting with the lead or tin, and either volatilizing, or changing them into a scoria, which is thrown off to the sides of the vessel. Small proportions of most of the other metals are in like manner separated from gold by sublimate; the acid having less affinity to the mercury of the sublimate than it has to the others, and accordingly parting from the former to join itself to the latter.

When gold is changed to the appearance of a calx, by precipitation from aqua regia with volatile or fixt alkalies, of which hereafter; or by calcination in mixture with tin or bismuth, as mentioned towards the end of the preceding section, the pure marine acid, by the assistance of a moderate heat, perfectly dissolves it. I have found that even a weak spirit of salt will take up gold so prepared, though in no great quantity; and that the gold does not precipitate from this as from the nitrous acid, but continues durably suspended.

## III. *Gold*



### III. *Gold with the Vitriolic acid.*

THE vitriolic acid, in whatever manner applied, has not been observed to have any action on gold, or to promote the action of other acids. Hence, as oil of vitriol dissolves silver by a boiling heat, silver and gold may be parted from one another by this acid, as effectually, though not so commodiously, as by the nitrous. If the compound be reduced into grains or thin plates, and boiled in about twice its weight of oil of vitriol to dryness, the silver will be so far corroded, as to be easily washed off by a little more of the acid; or if the mass, after the corrosion, be melted in a crucible, the gold will separate and subside, the silver forming a scoria above it. Gold may thus also be purified from several other metallic bodies: Mr. Scheffer says, that this is the most direct way of separating tin from gold.

### IV. *Gold with compound menstrua.*

GOLD is said to be dissolved by the marine acid mixed with a small proportion of spirit of urine; by a mixture of the vitriolic acid with the same urinous spirit; by a mixture of the vitriolic acid with a little fixt alkaline salt; by the vapour, which arises during the effervescence of the vitriolic acid with fixt alkaline salt, collected by distillation; in a spirit, prepared by saturating the vitriolic acid with volatile alkaline salt, exsiccating the mixture, dissolving it in twice or thrice its quantity of aqua fortis, and distilling the solution. In my experiments, not one of these liquors appeared to have any action on gold.

The most effectual menstruum of gold is a mixture of the nitrous and marine acids, called aqua regia; which, in a moderate heat, readily and totally dissolves it into a  
transparent

transparent yellow liquor. As this compound does not at all dissolve silver, the gold may be extracted by it from a mixture of gold and silver, in the same manner as the silver is extracted by aqua fortis; and as the extraction of the silver by aqua fortis requires the quantity of silver in the mixt to exceed that of the gold, so the extraction of the gold by aqua regia requires the gold to exceed the silver: the two metals may be so proportioned, that neither aqua fortis nor aqua regia shall be able to dissolve either, till an addition is made to the quantity of one or the other metal.

When the quantity of gold in the mixt amounts to so much as a third part of the silver, aqua fortis leaves always a small portion of the silver undissolved along with the gold; and in like manner, when the quantity of gold amounts to so much as a third of the silver, aqua regia leaves a little of the gold undissolved along with the silver: when either metal is in small proportion, the other appears to be completely extracted by its proper menstruum. If the gold, remaining after the parting with aqua fortis, be dissolved in aqua regia, the silver it had retained will separate and be left undissolved: and if the silver, remaining after the parting with aqua regia, be dissolved in aqua fortis, the gold it had retained will in like manner separate. This experiment affords a method of determining the precise quantity of either metal retained by the other, and a proof of the erroneousness of the opinion of some writers, that so much silver, as gold retains in parting, is actually transmuted into gold.

Aqua regia may be prepared, by dissolving powdered sea salt or sal ammoniac in four times their weight of aqua fortis, or by dissolving nitre in four times its weight of spirit of salt, or by mixing the pure spirits of nitre and sea salt together. The first is the method most commonly followed.

followed. Kunckel observes, that by putting the gold into the aqua fortis first, and then adding the salt by little and little at a time, less of the menstruum will suffice than if the salt was previously dissolved in the acid; the conflict, excited by each addition of the salt, promoting the dissolution of the gold: this method appeared upon comparison to have a sensible advantage above the other, whether the sal ammoniac directed by Kunckel, or common salt was used: the common salt is to be preferred; for sal ammoniac, especially when a strong heat is called in aid to hasten the solution, is apt to occasion some small part of the gold to be dissipated during the effervescence.

A solution in water of common salt, nitre and alum, boiled with leaf gold to dryness; or the salts in substance, mixed with the gold leaf, and urged with a slight red heat for some hours in a close vessel; corrode a considerable quantity of the gold into a saline form so as to be dissolved upon adding water. The mixture of these salts, from its acting insensibly and without effervescence, has been commonly called *menstruum sine strepitu*: it can be considered no otherwise than as an impure aqua regia, acting only by virtue of the acids of the nitre and marine salt, which are extricated from their bases by the acid of the alum.

#### V. *General properties of solutions of gold.*

SOLUTION of gold, whether made in spirit of salt, or in any of the foregoing aquæ regiæ, is of a bright yellow colour, resembling that of gold itself. It stains the skin of a deep purple colour, which cannot be washed out; and gives a like durable stain, though with some variations in the species of the colour, to sundry animal and vegetable substances, as dressed leather, ivory and bones, feathers, woollen cloth, silk, linen, cotton, wood:

to marble it imparts a violet or purplish colour, which penetrates to a considerable depth, but on the harder stones, as agates, it makes little impression, communicating only a superficial brown tinge. The solution for these purposes, should be prepared in Kunckel's method, that the acid may be fully saturated with the metal, and have as little admixture as may be of the saline matter : it should be diluted with three or four times its quantity of water, and if the colour is required deep, the piece, when dry, is to be repeatedly moistened with it. Animal substances should be previously well cleansed from their unctuousity, and soaked for some time in water : the others require no preparation of this kind. The colour does not take place till a considerable time, sometimes several days, after the liquor has been applied, and on some subjects it is more slow than on others : to hasten its appearance, the subject should be exposed to the sun and free air, and occasionally removed into a moist place, or moistened with water.

. When solution of gold in aqua regia is soaked up in linen cloths, and the cloths dried and burnt, the particles of gold remain blended in the brown coaly powder, which, being moistened with a little water, and rubbed on silver well cleaned from any unctuous matter, gilds it, without the application of heat, or the intervention of any other body : this is a ready but not a frugal way of applying gold on silver.

If the menstruum has been prepared with an addition of sea salt, nitre, or sal ammoniac, and the solution is set in a warm place, in a vessel slightly covered, so as to keep out dust, without preventing the evaporation of the watery part of the liquor ; the gold, combined with the saline matter, shoots into yellow crystals, commonly small and irregular. Solutions in the pure marine acid, and  
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in mixtures of the pure acids of nitre and sea salt, are very difficultly made to crystallize : in order to the crystallization of these, the liquor should be evaporated till only about one half of it remains, and then set by in the cold with the addition of a few drops of pure spirit of wine. The crystals obtained from high coloured saturated solutions are generally of a red colour, and sometimes, as is said, of a deep ruby red.

On distilling with a gradual fire a solution of gold made in strong aqua regia, an acid spirit comes over, which, from its rising in red fumes, and from its dissolving silver, appears to be the nitrous acid. On continuing the distillation, whitish fumes succeed, a mark that part of the marine acid begins to rise ; though, after the operation has been protracted till the residuum becomes dry, the gold still retains so much of the acid as to be dissoluble in water : it appears to be chiefly, if not solely, the marine acid which thus remains combined with the gold ; on which foundation, the nitrous acid, employed for the dissolution of the gold, may be nearly all recovered, and its place supplied by an equal quantity of common water ; the marine spirit, though ineffectual for procuring the dissolution of the metal in its common form, being sufficient for keeping it dissolved. When the matter has just become dry, it appears of a deep red colour : on further increasing the fire, the acid is totally dissipated, and the gold remains in powder, extremely subtile, and of its proper hue. This is a convenient method of obtaining a fine powder of gold : if the aqua regia has been made with an addition of nitre or sea salt in substance, the saline matter, left with the gold, may be separated by water. The most eligible aqua regia, for the above purpose, is a mixture of the pure acids, or of the nitrous acid and sal ammoniac ; for these will be wholly dissipated by

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fire,

fire, and the gold alone left. If the powder is moistened with a solution of borax, it may be applied with a pencil on glass or porcelain, and by a suitable heat durably fixed upon them.

On inspissating nearly to dryness a solution of gold made in an aqua regia prepared with common sal ammoniac, abstracting from the residuum several fresh quantities of the same kind of aqua regia, and at length increasing the fire somewhat hastily towards the end of the distillation; the acid carries over with it a portion of the gold, sufficient to communicate a yellow or a red tinge; and a more considerable quantity of the gold, united with the more concentrated acid, sublimes, of a deep red colour, into the neck of the retort, concreting partly into long slender crystals, and partly into a firm substance closely applied on the glass: the crystals lie so loose, that they are apt to fall down again on moving the vessel; though, if this should happen, after the matter has become cold, they may be easily separated again, the residuum growing firm as it cools: both the crystals and the compact sublimate dissolve easily in water, deliquesce in the air, and melt with a small heat. By adding to the residuum more aqua regia, and repeating the distillation several times, the whole of the gold may thus be made to rise.

Common aqua regia, prepared with rough sal ammoniac, appears to volatilize the gold as effectually, as any of the more operose compositions recommended for this purpose by the chemical writers. The rough sal ammoniac must necessarily be used, not such as has been purified, as it is called, by sublimation; for Dr. Brandt observes, that if the sal ammoniac be first sublimed with a sufficiently strong heat, and then dissolved in spirit of nitre, the aqua regia thus prepared will not make gold volatile. He finds, that when the gold has been dissolved, and the menstruum

distilled off, there remains in the retort a saline mass, containing the gold; that on every fresh solution and distillation with the same kind of aqua regia, the matter increases more and more in its weight, and looks like a foul dark brown salt very hard of fusion; that the liquor which distils is clear as water, and that nothing of the gold sublimes. He observes also, that an aqua regia made with nitre in substance and the acid spirit of sea salt, and with sea salt in substance and the acid of nitre, have less effect in volatilizing gold than that with rough sal ammoniac above mentioned.

Though many have expected, from this volatilization of gold, a resolution of it into dissimilar parts, it is not found to have suffered any real change. If the distilled liquor, or the crystals, or the sublimate, be exposed to a heat gradually increased, the acid rises, without carrying with it any part of the metal, the gold being left entire behind. The menstruum is less disposed to elevate the gold a second time, than it was at first.

#### VI. *Separation of gold from acids by inflammable liquors.*

THE very subtle inflammable fluid, obtained from a mixture of vitriolic acid with vinous spirits, commonly called æther, or æthereal spirit of wine, poured into a solution of gold made in aqua regia or in spirit of salt, floats distinct upon the surface, being far lighter than the acid liquor and not at all miscible with it. The æther, of itself colourless, quickly becomes yellow, and the acid underneath loses proportionably of its yellowness; the æther imbibing the gold, keeping it permanently dissolved, and, when loaded with the ponderous metal, continuing still to float upon the acid. Gold is the only one, of the known metals, which the æther takes up from acids, and hence this fluid affords a ready method of distin-

distinguishing gold contained in acid solutions : whether a small quantity of some other metals may not, in certain circumstances, accompany the gold in this separation from the acid, or whether very large quantities of some metals will not defend a minute portion of gold from the action of the æther, may deserve further enquiry ; though such experiments, as we have hitherto made, incline us to think that they will not. The æther imbibes the gold, though it lies only on the surface of the acid solution : nevertheless, to hasten the effect, and to secure against any particles of the gold escaping its action, it is expedient to shake them lightly together, the vessel being closely stopp'd to prevent the evaporation of this very volatile fluid. If the solution in æther, poured off from the acid, be exposed to the open air, the æther exhales in a few minutes, leaving the gold behind ; if kept for some months in a slender glass stopp'd so as that the æther may exhale exceeding slowly, the gold does not resume its proper form, but shoots, as is said in the Swedish transactions, into crystals, of a transparent yellow colour, a long prismatic figure, and an austere taste.

Essential oils, shaken with solution of gold, imbibe the gold in like manner, and carry it up to the surface, but keep it dissolved only for a little time : the metal gradually separates, and is thrown off to the sides of the glass in bright yellow films, which on shaking the vessel fall to the bottom. The oil, though of itself colourless, continues coloured after the gold has parted from it, essential oils receiving from the pure acid, first a yellow, and afterwards a reddish hue. Hence where these oils are employed as a test of gold in solutions, it is not the colour which the oil acquires, but the separation of the golden films, that is to be regarded. The  
oils



oils appear to be more sluggish than the æther in taking up the gold, and hence require to be well shaken with the solution.

Rectified spirit of wine mingles uniformly with the acid solution, and does not, for a time, occasion any other apparent change than rendering its colour more dilute. When the solution of gold has been inspissated to dryness, the metal, with the acid that remains combined with it, dissolves in spirit of wine: if the menstruum was either the pure marine acid, or a mixture of the pure nitrous and marine acids, or a mixture of the nitrous acid and sal ammoniac, the inspissated matter dissolves totally in the vinous spirit: if the aqua regia was made by dissolving sea salt in aqua fortis, or by dissolving nitre in spirit of salt, the neutral saline compounds contained in these menstrua not being dissoluble in vinous spirits, remain perfectly white after the extraction of the gold. From all these mixtures, as from essential oils, the gold separates by degrees, though less speedily. On standing for some days, especially if the glass is but lightly covered, the metal is seen floating in fine bright yellow pellicles upon the surface. The addition of a little essential oil to the spirit hastens the separation of the gold.

Here it may be observed, that many of those, who have busied themselves in the pursuit of medicinal preparations from gold, have been greatly deceived in the result of their operations, from not being acquainted with the above properties of the metal. Finding that essential oils imbibe gold from aqua regia, and receive with the gold a high colour, and that rectified spirit of wine, by digestion with the oil, dissolves it, and becomes impregnated with its colour; they imagined they had thus obtained an *aurum potabile*, or true tincture of the gold,  
which:

which they supposed to be endowed with extraordinary medicinal powers; not aware, that the gold constantly separated in the process, and that the colour of the preparation was no other than that which concentrated acids produce with essential oils however pale or colourless.

Liquors containing a grosser inflammable matter, as wine, vinegar, solution of tartar, are likewise found to extricate gold from aqua regia in its metallic form; with this difference from the preceding, that the gold, instead of floating on the surface, falls here generally to the bottom.

#### VII. *Precipitation of gold by alkaline salts.*

ON adding to solution of gold a solution of any fixt alkaline salt or a volatile alkaline spirit, in sufficient quantity to satiate the acid; the mixture becomes turbid, and on standing for some hours, the gold falls to the bottom, in form of a brownish yellow muddy substance, retaining some of the saline matter, great part of which may be separated by repeated washing with hot water. That the gold may precipitate the more freely, the solution should be diluted with three or four times its quantity of water, or more. The alkaline liquor should be added by degrees, in little quantities at a time, till the mixture, after the gold has settled, appears colourless, and a fresh addition of the alkali occasions no further precipitation or turbidness.

When gold has been thus totally precipitated by volatile alkaline spirits, as spirit of sal ammoniac, the addition of more of the spirit renders the liquor again yellow, occasioning a part of the gold to be redissolved: by adding a large quantity of the alkaline spirit, almost all the precipitate is taken up; and even when the precipitated gold has been washed from as much of the adhering saline matter

matter as water will easily extract, a considerable part of it will still dissolve in pure volatile spirits, but not so much as before the ablution : I have not observed the whole of the gold to be taken up in either case, though some report that they have found it to be so in both. Pure fixt alkalies, added in large quantity after the precipitation, do not appear to redissolve any of the gold.

If the aqua regia has been prepared with sal ammoniac, or if the precipitation is performed with a volatile alkali, the unwashed precipitate explodes, on being heated, with a bright flash and a smart noise ; whence its name *aurum fulminans*. If the aqua regia has been made without sal ammoniac, and the precipitation is performed with a fixt alkali, the precipitated gold makes no explosion : gradually heated, it changes its dull yellowish to a bright purple or purple-violet colour, and on further increasing the heat resumes its metallic aspect. A volatile alkaline salt, either in the dissolvent or in the precipitant, seems to be essentially necessary to the fulmination.

Aurum fulminans weighs about one fourth part more than the gold employed, three parts of gold yielding four of the fulminating powder : this I relate on the authority of Lemery, Kunckel, and other practical writers, for though I have often made the preparation myself, I have never examined the increase of its weight. Part of the increase proceeds from the volatile alkali ; for on adding to the aurum fulminans a little vitriolic acid, the volatile salt rises in sublimation, satiated with the acid : the remaining powder is found to be divested of its fulminating power. From the coalition of the volatile alkali with the nitrous acid in the menstruum results an ammoniacal nitre, a salt which of itself detonates on being heated : by what power or mechanism its detonating quality is so remarkably increased in the aurum fulminans, is unknown.

The explosion of aurum fulminans is more vehement than that of any other known kind of matter : it goes off in a less degree of heat than any of the other explosive compositions ; and even grinding it somewhat smartly in a mortar is sufficient for making it explode. Some instances are mentioned in the Breslau collections, and the *ephemerides naturæ curiosorum*, of a very small quantity bursting in pieces the marble mortar in which it was rubbed ; and an accident of the same kind happened some years ago to a skilful chemist here. The operator cannot be too much on his guard in the management of so dangerous a preparation.

It has been reckoned, that a few grains of aurum fulminans act with as much force as several ounces of gunpowder : but the actions of the two are of so different kinds, that I cannot apprehend in what manner their strength can be compared. The report of aurum fulminans is of extreme acuteness, offending the ear far more than that of a much larger quantity of gunpowder, but does not extend to so great a distance ; seeming to differ from it as the sound of a short or tense musical string from that of a long one or of one which is less stretched. In some experiments made before the royal society and mentioned in the first volume of Dr. Birch's history, aurum fulminans closed up in a strong hollow iron ball and heated in the fire, did not appear to explode at all ; while gunpowder treated in the same manner burst the ball. On the other hand a little aurum fulminans, exploded on a metalline plate in the open air, makes an impression or perforation in the plate ; an effect which gunpowder could scarcely produce in any quantity.

This remarkable effect of aurum fulminans on the body which serves for its support, has induced some to believe that its action is exerted chiefly or solely downwards.

It appears however to act in all directions: for a weight, laid upon it, either receives a like impression, or is thrown off; and in the collections above mentioned an account is given of a large quantity (some ounces) which exploding from too great heat used in the drying of it, broke open the doors and shattered the windows in pieces. Mr. Hellot found, that when a few grains of the powder were placed between two leaves of paper, and cemented to one of them by gum water, only the leaf which touched the powder was torn by the explosion, and the other swelled out; and that when both were brought into close contact with it, by pressing them together, it tore them both; from whence he concludes, that the action of the aurum is greatest on the bodies which it immediately touches. Both this property, and the acuteness of the report, may possibly depend upon one cause, the celerity of the expansion: experiments have shewn, that the resistance of the air to bodies in motion increases with the velocity of the body in a very high ratio; and perhaps the velocity with which aurum fulminans explodes may be so great, that it is resisted by the air as by a solid mass.

The explosion of this preparation does not appear to make any change in the gold. When the powder is spread exceeding thin between leaves of paper, and slowly heated, the detonation, as Mr. Hellot observes, is slight and successive, the powder becomes purple, and appears of the same quality with the precipitate above mentioned which has no fulminating power. When a quantity is made to explode at once, in a large vessel, or under a proper cover, for confining the particles violently dispersed, the gold is found in fine dust, partly purplish and partly of its proper yellow colour: it is said that when

the explosion is performed between silver or copper plates, the revived gold adheres to and gilds some part of their surface.

If aurum fulminans be washed with fresh portions of hot water, that as much as possible of the saline matter may be extracted, its fulminating quality will be greatly diminished. If ground with oil of vitriol, which expels the nitrous acid, and unites with the volatile alkali, or boiled in a solution of fixt alkaline salt, which expels the volatile alkali, and unites with the nitrous acid, it no longer makes the least explosion, and the gold may be recovered by simple fusion. When mixed with sulphur, and exposed to a gentle fire, the sulphur gradually burns off, and leaves the gold in like manner recoverable without danger of fulmination. In all these cases, if treated with a slow fire, it generally assumes a purple colour before it returns to its metallic form.

#### VIII. *Precipitation of gold by metallic bodies.*

ALL the metallic bodies that dissolve in aqua regia, platina excepted, precipitate gold from it; the acid parting from the gold, and dissolving a portion of the others in its room. Some of them precipitate it also when they are previously dissolved in other acids, and even in aqua regia itself.

Iron, in certain circumstances, becomes covered with the gold which it extricates from the acid, particularly where vinous spirits have been mixed with the solution. A liquor prepared by boiling gold leaf in water with nitre, sea salt, and alum, till the matter becomes dry, and then digesting the mixt in rectified spirit of wine, is said to answer the best for the gilding of iron in this way; tho' it does not appear to have any different effects from those of other mixtures of spirit of wine with solution of gold.

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A solution of gold in common aqua regia being largely diluted with spirit of wine, a polished iron, dipt in the mixture, became immediately coated with a fine golden pellicle : the gold solution without the spirit of wine corroded the iron, and raised a scurf upon the surface. These mixtures should be prepared only as they are wanted, for on standing for a day or two the gold begins to separate.

Iron dissolved in the vitriolic acid, or common green vitriol dissolved in water, precipitates gold in form of a dusky brown-red powder. As the vitriolic solutions of iron do not precipitate from aqua regia any known metallic body besides gold, this experiment affords a commodious method of purifying gold from the smallest admixture of other metals : the particular way of managing the process will be given under the head of refining gold, in the ninth section.

On adding copper to a solution of gold in aqua regia diluted with water, the copper became instantly of a blackish red colour ; and on standing, the gold fell in subtile powder, of its proper metallic aspect, and of a high reddish colour, which probably proceeds from some cupreous atoms intermixed : it is remarkable in this experiment, that the liquor, after the precipitation of the gold, appears colourless as water, a proof that the quantity of copper, taken up in the place of the gold, must be extremely minute. Solutions of copper in the vitriolic acid, or of blue vitriol in water, produced no precipitation or turbidness in solution of gold. Copper or verdegris dissolved in vinegar occasioned the gold to separate in bright films, which covered the sides of the glass, forming an almost continuous golden pellicle : this separation however seems to depend, not so much upon the copper, as on the inflammable matter of the vinegar.

A plate of pure tin, put into a solution of gold largely diluted with water, changes the yellowish colour of the liquor to a beautiful purple or red : by degrees, a powder of the same colour slowly subsides, and leaves the menstruum colourless. Solutions of tin, made in aqua regia, have the same effect with tin itself, in regard both to the precipitation and the colour ; and hence characters, drawn on paper with a diluted solution of gold, not visible when dry, become immediately red or purple on passing over them a diluted solution of tin. With the undiluted solutions, no redness is produced : after the red powder has fallen from the diluted liquor, if the whole be set in a moderate warmth till the water has exhaled, the gold is taken up again, the liquor becomes yellow as at first, and only a white powder remains, which appears to be a calx of tin. The red liquor, set to evaporate before the gold has fallen, yields only a yellow mass ; from which rectified spirit of wine extracts the gold combined with the acid, leaving, as in the other case, a white calx of tin.

Mercury, dissolved in the vitriolic, nitrous, or marine acids, is a precipitant for gold, as well as in its metallic form ; and in all cases, a part of the mercury is apt to fall down along with the gold. When mercury in substance is used, and the solution of gold largely diluted, the undissolved mercury gradually imbibes the gold.

On dropping a solution of silver into one of gold, both metals precipitate : the silver, parting from the nitrous, unites and falls with the marine acid, and the gold falls for want of it : the matter which separates first is white, then the liquor grows opake and a dark coloured powder subsides, which leaves the menstruum clear and capable of dissolving silver. The same double precipitation happens,



pens, and on the same principle, on mixing solution of gold with solution of lead in aqua fortis.

### IX. *Gold with sulphureous bodies.*

PURE sulphur, whose fumes corrode, and which in fusion dissolves and scorifies most metallic bodies, has no action on gold. Hence the use of gold for some mechanic purposes, where other metals are in time destroyed by sulphureous fumes; as in the touch-holes of guns. And hence by fusion with this concrete, gold may be separated from most of the other metals. From silver and copper it may be extracted, on this principle, where the proportion of gold is too small to bear the expences of the other common methods of separation: some particular managements and additions, however, are requisite, to render the process successful; see section the ninth.

Though gold resists pure sulphur, it unites perfectly with a mixture of sulphur and fixt alkaline salt, commonly called *hepar sulphuris*. As soon as the hepar melts, it begins to dissolve the gold, with a lucid ebullition: two or three parts of sulphur, and three of the alkaline salt, are sufficient for one of gold. Great part of the compound dissolves in water, so as to pass through a filter without any separation of the metal: Stahl observes, that this solution is less offensive in smell than that of the hepar itself, but of a more bitter nauseous taste.

The addition of any acid to this solution, absorbing the alkaline salt, precipitates the gold united with the sulphur; which last may be dissipated by fire, or more readily separated by adding a little copper for absorbing the sulphur. A like separation may be obtained by adding copper or iron to the mixture of gold and hepar in fusion; these metals precipitating the gold, and uniting with the hepar in its place. Mr. Hellot recommends detonation  
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with nitre as the easiest method of recovering the gold from the sulphureous mixture: the best way of managing this process appears to be, by making the matter red hot in a deep crucible, and dropping in the nitre, which should be previously well dried and heated, by a very little at a time, as the addition of any considerable quantity at once would occasion the deflagration to be so strong as to force off some particles of the gold: this is the only inconvenience in the process, and it is not to be wholly avoided without great precaution; for in many experiments of melting gold with nitre, when inflammable bodies had been mixed with the gold, I have almost always observed numerous globules of the metal thrown up about the sides of the crucible: when a fresh addition of the nitre produces no further deflagration, the fire is to be increased so as to bring the whole into fusion; and the crucible being then suffered to cool, the gold is found at the bottom of the saline mass, pure and of a high colour.

A neutral salt, composed of fixt alkaline salt saturated with the vitriolic acid, being brought into fusion in a close crucible, with the addition of a little foot or powdered charcoal; the vitriolic acid and inflammable principle unite together, and form sulphur, the same with common brimstone, which remaining combined with the alkali, the compound proves a true hepar sulphuris: and accordingly gold, melted with these ingredients, is dissolved by them in the same manner as by a hepar already made.

Dr. Brandt gives an account of an experiment, from which he concludes, that gold, by being dissolved in the above mixture, and afterwards recovered from it, suffers a considerable change. About a grain of gold and two hundred grains of silver were melted with the mixture, and

and precipitated by adding twice as much copper : the scoria, containing the copper, was melted with calx of lead, and the lead revived from the compound, that if any of the gold and silver should have remained in the scoria, they might be imbibed by the lead : the precipitated mass was cupelled with the revived lead, and then parted by aqua fortis : the gold powder, which the aqua fortis left undissolved, differed somewhat in appearance from that which commonly remains in parting, and being melted with a pure white fixt alkaline salt, the gold turned out pale and almost like silver. I have not yet repeated this experiment, and do not apprehend that it will bear any great stress to be laid upon it. It is more probable that the gold retained a part of the extraneous matter, than that it suffered itself any real change. The author observes that the crucible, in which the gold powder was melted, had a green tinge round its edge, and that the alkaline salt was coloured yellow, but that the gold after the fusion was found to be of its full weight ; so that a part of the gold might have been dissolved and retained by the salt, and an equal quantity of other matter remained blended with the rest of the gold.

The phosphorus of urine has been said by some to reduce gold into a red mucilage. By digestion or distillation in close vessels, as a retort and receiver, the phosphorus appears to have no action on gold : this I relate on the authority of Mr. Margraff, whose experiments, in the *Miscellanea Berolinensia* for the year 1740, have saved me the trouble of this examination : gold filings were digested with thrice their weight of phosphorus for four weeks, and the fire being then increased, part of the phosphorus sublimed, and part remained above the gold, in appearance like fine glass : this last grew moist on the admission of air, and dissolved in water, leaving the gold

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unchanged. Nor does gold appear to be affected by the fumes of phosphorus set on fire. But the flowers or saline acid matter remaining after the inflammable principle of the phosphorus has been consumed, and the microcosmic salt or essential salt of urine, which contains this acid, being melted along with gold in a moderately strong fire, manifestly corrode the metal, and receive from it a purple tinge.

## S E C T. VII.

*Of the alloy of gold; and the methods of judging of the quantity of alloy it contains, from the colour and weight.*

### I. *Of the alloy of gold.*

**G**OLD, in its pure state, is reckoned too soft and flexible for the common purposes of coins and utensils; and hence, to increase its hardness, and render it better adapted to these uses, it is allowed to be mixed with a certain quantity of inferior metals; which, in respect to the gold, are called alloy, and whose proportion is settled by law. That these admixtures are of so much advantage, in regard to the use of the metal, as has been commonly thought, may perhaps be questioned: for though fine gold may be scratched or bent easier than such as is alloyed, yet (as is observed in a judicious Essay on money and coins published in 1758) the alloyed appears to be diminished more by wearing than the fine.

There are cases in which an admixture of alloy appears absolutely necessary, as particularly in gold plates for being enamelled. If the plates are made of fine gold, they bend, and change their figure, in the heat requisite for making the enamel melt: the workmen find, that the quantity of alloy, permitted in coins, prevents this inconvenience;

venience ; and that a greater quantity cannot be employed, as it would occasion the gold to melt.

From the account given in the fifth section, of the effects of different metals upon gold, it appears, that silver and copper are the only ones fit for serving as its alloy ; all the others debasing its beauty, and greatly injuring or destroying its malleability. Happily also these are the two metals which are ofteneft naturally blended with it in the mines, fo that the trouble and expence of refining it are thus greatly leffened. As the natural alloy is frequently in a smaller proportion than the ftandard quantity, as well as in a greater, it is plain that gold below the ftandard fineness may frequently be brought to the ftandard, without any refining at all, by melting it with a due proportion of fuch as is above the ftandard. In this view, the admitting of alloy, for all thofe intentions in which it is not injurious, is of manifelt advantage.

The degree of fineness of gold, or the proportion of alloy it contains, is accounted by imaginary weights called carats. The whole mafs is conceived to be divided into twenty-four carats ; and fo many twenty-fourth parts as it contains of pure gold, it is called gold of fo many carats, or fo many carats fine. Thus gold of eighteen carats is a mixt, of which eighteen parts in twenty-four are pure gold, and the other fix parts an inferiour metal ; and in like manner gold of twenty carats contains twenty parts of pure gold to four of the alloy. This is the common way of reckoning in Europe, and at the gold mines in the Spanifh weft Indies, but with fome variation in the fubdivifion of the carat : among us, it is divided into four grains ; among the Germans, as appears from the treatifes of Ercker, Cramer, and other German affayers, into twelve parts ; and by the French, according to Mr. Hellot, into thirty-two. The Chinefe reckon

by a different division, called touches, of which the highest number, or that which denotes pure gold, is one hundred ; so that a hundred touches correspond to our twenty-four carats, seventy-five touches to eighteen carats, fifty touches to twelve carats, and twenty-five to six ; from whence any number of the one division may be easily reduced to the other.

The standard gold of this kingdom is of twenty-two carats, that is, it consists of twenty-two parts of fine gold and two of alloy : the alloy is more commonly a mixture of silver and copper, than either of them alone ; silver alone, in so considerable a quantity, giving too great a paleness to the gold, and copper alone too great a redness. It is difficult for the assayer, as we shall see hereafter, to determine with minute exactness the fineness of a given mass of gold ; and it is not to be expected that the workman, in every piece intended for standard gold, should be able to attain to the exact standard proportion of alloy. In the English coinage, which all possible precautions are taken to keep as near as may be to the standard, a certain latitude is allowed in this respect, called the remedy for the master of the mint. Out of every fifteen pounds of gold coined at the mint, (according to the account published by the learned Mr. Folkes, late president of the royal society, in his curious tables of English silver coins) some pieces are taken at random, and deposited in a strong box called the pix : at certain intervals, sometimes of one year and sometimes several years, the pix is opened at Westminster, in the presence of the lord chancellor, the lords commissioners of the treasury and others ; portions taken from the pieces of each coinage are melted together, and an assay made of the collective mass by a jury of the goldsmiths company. At this trial the mint-master is held excusable, though  
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the moneys be either too base or too light, provided the imperfection and deficiency together are less than the sixth part of a carat, which amounts to forty grains of fine gold on the pound of standard, or the one hundred and thirty-second part of the value. It is said that this remedy is contained within as narrow limits, as any workers can reasonably be supposed to make themselves answerable for.

The proportion of alloy in other nations is various. According to the assays of sundry foreign coins, made at the Tower by the direction of Sir Isaac Newton, and published in Arbuthnot's tables of coins, the moidores of Portugal and their subdivisions, and the old pistoles and doubloons of Spain and Italy, are a little worse than our standard, but within the latitude allowed to our own mint-master: the new louis d'or of France is about a fifth of a carat below that latitude. The ducats of Germany, Holland, Sweden and Denmark are a carat and a half better than standard; and the sequin of Venice, the finest of all the modern European coins, is a carat and seven eighths better, or only an eighth of a carat worse than fine gold.

The standard gold of England was formerly of the same fineness with the Venetian sequin, to wit, twenty-three carats three grains and a half. Our present standard of twenty-two carats, was introduced in 1527, (about 270 years after the commencement of our gold coinage) for a particular sort of coin called crowns, of equal value with those of the same name which have since been formed of silver, and hence this kind of gold has been frequently distinguished by the name of crown gold. Both the old and the new standard were continued to 1642, since which period only the latter has been used. The remedy for the master of the mint has been almost always

an eighth part of a carat for the old standard, and a sixth of a carat for the new.

A pound of standard gold, in the English coinage, is cut into forty-four guineas and a half; so that the mint price of fine gold is four pounds four shillings and eleven pence halfpenny an ounce nearly. Lower than this the price of gold bullion cannot fall, the mint being always ready to exchange it on that footing for coin; but there are fundry causes which may render it higher, and which it does not belong to the present purpose to examine: the reader may consult on this subject the essay on money and coins already quoted, where he will meet with abundant satisfaction.

A pound of standard silver, containing eleven ounces two pennyweights of fine silver, is cut into sixty-two shillings: whence the proportional value of fine gold to fine silver is, in our coinage, as fifteen and one fifth to one. Sir Isaac Newton observes, in a representation to the lords of the treasury in the year 1717, that in the mints of Spain and Portugal, the value of gold is sixteen times that of silver; but that in those countries, payments in silver bearing generally a premium of six per cent. the proportion may be looked upon as fixed by commerce at fifteen and one twenty-fifth to one: that in the other parts of Europe, the value of gold is at most fifteen, and in China and Japan but nine or ten times, that of silver: so that gold is rated higher in England than in any other part of Europe, and higher in Europe than in the eastern countries. Hence, in great measure, arise the profits of exchanging gold for silver in one place, and re-exchanging them in another; and hence the greater disparity between the relative quantities of gold and silver in one commercial nation than in another, that metal being brought in most abundance which is  
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rated highest in proportion to the other, and that which is rated lowest being drained away.

The alloy of gold, though it consists of silver, and though its quantity be greater than that of the standard proportion, down to certain limits, is reckoned as of no value : the value of the mass is estimated only from the quantity of fine gold it contains ; and from this, for every carat that it is below the standard fineness, there is commonly a deduction made, of four pence an ounce, for the charges of refining. A certain quantity of gold, mixed with silver, loses also its own value, and is reckoned only as a part of the silver. There can be no fixt limits for the proportions in which the value of one metal is thus absorbed by the other ; as they must depend on the expence of separating the two metals, in different places, by the operations there commonly practised. The author of the essay on money and coins above mentioned says he has been informed, that a pennyweight of gold in a pound of silver, or one part in two hundred and eighty-eight, is reckoned among us the least proportion of gold that will pay for refining, and that in this there is a profit only of about one farthing on the ounce.

## II. *Method of judging of the fineness of gold from its colour.*

THOSE who are accustomed to the inspection of gold variously alloyed, can judge nearly, from the colour of any given mass, the proportion of alloy it contains, provided the species of alloy is known. Different compositions of gold with different proportions of the metals which it is commonly alloyed with, are formed into oblong pieces, called needles, and kept in readiness, for assisting in this examination, as standards of comparison.

The proportions, in the composition of the several needles, are adjusted, in a regular series, according to the

carat weights as explained in the preceding article. The first needle consists of fine gold, or of twenty-four carats; the second, of twenty-three carats and a half of fine gold and half a carat of alloy; the third, of twenty-three carats of fine gold to one carat of alloy, and so on, the gold diminishing, and the alloy increasing, by half a carat in each needle, down to the twentieth carat: all below this are made at differences of whole carats, half a carat being scarcely distinguishable by the colour of the mass when the proportion of alloy is so considerable. Some make the needles no lower than to twelve carats, that is, a mixture of equal parts of gold and alloy: others go as low as one carat, or one part of gold to twenty-three of alloy.

Four sets of these needles are commonly directed; one, in which pure silver is used for the alloy; another with a mixture of two parts of silver and one of copper; the third with a mixture of two parts of copper to one of silver; and the fourth with equal parts of the two: to which some add a fifth set, with copper only, an alloy which sometimes occurs, though much more rarely than the others. If needles so low as three or four carats can be of any use, it should seem to be only in the first set: for in the others, the proportion of copper being large, the differences in colour of different sorts of copper itself will be as great, as those which result from very considerable differences in the quantity of gold. When the copper is nearly equal in quantity to the gold, very little can be judged from the colour of the mass.

In melting these compositions, the utmost care must be taken, that no loss may happen to any of the ingredients, so as to alter the proportions of the mixtures. The crucibles should be of the smoothest kind, that no particle of the metal may lodge about the sides. The copper should

should be taken in one round lump, that its surface being as small as possible, it may be the less disposed to be scorified: that this may be the more effectually guarded against, some inflammable matter, as pitch, resin, or a little charcoal in fine powder, should be added to the borax used as a flux; and the fusion should be expeditiously performed, so as that the copper may be no longer exposed to the fire, than is absolutely necessary for its due union with the others. The flux being previously melted in the crucible, and brought to a strong heat such as is sufficient for the melting of copper, the metals are to be dropt in: as soon as they appear perfectly fluid, the crucible, after being gently jogged or shaken to promote the collection and settling of the metal, is to be taken out of the fire, and set on some warm support, that the mixture may not cool too hastily. The fusion may be commodiously performed also, the quantity of the metals employed for this use being commonly small, by placing them in a cavity made in a piece of charcoal, and directing upon them, by a blow-pipe, the flame of a lamp: those who are accustomed to the use of the blow-pipe, will find this method rather more secure than that by the crucible, as well as more convenient and expeditious. In whatever manner the process is performed, the several masses must be weighed after the fusion; and if the least diminution has happened in any, fresh mixtures must be prepared in their room.

The colours are best examined by means of strokes drawn with the metals on a particular kind of stone, brought chiefly from Germany, and called from this use a touchstone; the best sort of which is of a deep black colour, moderately hard, and of a smooth but not polished surface. If it is too smooth, soft gold will not easily leave a mark upon it; and if rough, the mark proves imper-

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fect. If very hard, the frequent cleaning of it from the marks, by rubbing it with tripoli or a piece of charcoal wetted with water, gives the surface too great a smoothness; and if very soft, it is liable to be scratched in the cleaning. In want of the proper kind of stone, moderately smooth pieces of flint are the best substitutes: the more these approach in colour to the other, the better.

The piece of gold, to be examined, being well cleaned in some convenient part of its surface, a stroke is to be made with it on the stone; and another, close by it, with such of the touch-needles as appears to come the nearest to it in colour. If the colour of both, upon the stone, is exactly the same, it is judged that the given mass is of the same fineness with the needle: if different, another and another needle must be tried, till such a one is found as exactly corresponds to it. To do this readily, practice only can teach.

In making the strokes, both the given piece, and the needle of comparison, are to be rubbed several times backwards and forwards upon the stone, that the marks may be strong and full, not less than a quarter of an inch long, and about a tenth or an eighth of an inch broad: both marks are to be wetted before the examination of them, their colours being thus rendered more distinct. A stroke, which has been drawn some days, is never to be compared with a fresh one, as the colour may have suffered an alteration from the air; the fine atoms, left upon the touchstone, being much more susceptible of such alterations than the metal in the mass. If the piece is supposed to be superficially heightened by art in its colour, that part of it, which the stroke is designed to be made with, should be previously rubbed on another part of the stone, or rather on a rougher kind of stone than the common touchstones, that a fresh surface of the metal may be exposed.

exposed. If it is suspected to be gilt with a thick coat of metal finer than the internal part, it should be raised with a graver, to some depth, that the exterior coat may be broken through : cutting the piece in two is a less certain way of discovering this abuse ; the outer coat being frequently drawn along by the sheers or chisel, so as to cover the divided parts.

The metallic compositions, made to resemble gold in colour, are readily known by means of a drop or two of aqua fortis, which has no effect upon gold, but dissolves or discharges the marks made by all its known imitations. That the touchstone may be able to support this trial, it becomes a necessary character of it not to be corrodible by acids ; a character which shews it to be essentially different from the marbles, whereof it is by many writers reckoned a species. If gold is debased by an admixture of any considerable quantity of these compositions, aqua fortis will in this case also discharge so much of the mark as was made by the base metal, and leave only that of the gold, which will now appear discontinued or in specks. Silver and copper are in like manner eaten out from gold on the touchstone, and hence some judgement may thus be formed of the fineness of the metal from the proportion of the remaining gold to the vacuities.

Ercker observes that hard gold appears on the touchstone less fine than it really is. It may be presumed that this difference does not proceed from the simple hardness : but from the hardness being occasioned by an admixture of such metallic bodies, as debase the colour in a greater degree than an equal quantity of the common alloy. Silver and copper are the only metals usually found mixed with gold whether in bullion or in coins ; and the only ones, whose quantity is attempted to be judged of by this method of trial.

The Chinese are said to be extremely expert in the use of the touchstone, so as to distinguish by it so small a difference in the fineness as half a touch, or a two hundredth part of the mixt. The touchstone, as I am informed, is the only test, by which they regulate the sale of their gold to the European merchants; and in those countries it is subject to fewer difficulties than among us, on account of the uniformity of the alloy, which there is almost always silver; the least appearance of copper being used in the alloy gives a suspicion of fraud. As an assay of the gold is rarely permitted in that commerce, it behoves the European trader to be well practised in this way of examination: by carefully attending to the above directions, and by accustoming himself to compare the colours of a good set of touch-needles, it is presumed he will be able to avoid being imposed on, either in the touch itself, or by the abuses, said to be sometimes committed, of covering the bar or ingot with a thick coat of finer metal than the interior part, or of including masses of base metal within it. A set of needles may be prepared, for this use, with silver alloy, in the series of the Chinese touches; or the needles of the European account may be easily accommodated to the Chinese, by means of a table formed for that purpose on the principles already explained. It may be observed, that the gold shoes of China have a depression in the middle, from the shrinking of the metal in its cooling, with a number of circular rings, like those on the balls of the fingers, but larger: I have been told, that when any other metallic mass is included within, the fraud is discoverable at sight, by the middle being elevated instead of depressed, and the sides being uneven and knobby; but that the same kind of fraud is sometimes practised in the gold bars, where it is not discoverable by any external mark.

### III. *Of estimating the fineness of gold from its gravity.*

THE great excess of the weight of gold, above that of the metals used for its alloy, affords another method of judging of the quantity of alloy or debasement, in any given mixture where the species of alloy is known.

It may here be proper to caution the reader against an error which has sometimes been fallen into, in computing the specific gravities of mixts from those of their ingredients. If the gravity of one metal was nine, and that of another eighteen, it has been inadvertently reckoned that the gravity of a mixture of equal parts of the two would be the medium between nine and eighteen, or thirteen and a half. If by equal parts were meant equal bulks, this would indeed be the case; but when the parts are taken by weight, as they are always understood to be in mixtures of this kind, it is otherwise. For eighteen weights of the one metal, on being immersed in water, will lose two, and eighteen of the other will lose one; so that thirty-six of the mixt will lose three: whence the specific gravity (which is found by dividing the weight in air by the loss in water) instead of being thirteen and a half, turns out but twelve.

Fine gold, as we have seen before, loses in water one grain in every nineteen and three tenths nearly; whereas fine silver loses one grain in about eleven: from whence it is easy to find the loss of any number of grains of each, and consequently of any assignable mixture of the two metals. Thus fifty grains of gold will lose above two and a half, and fifty grains of silver somewhat more than four and a half; so that a mixture of equal parts of the two will lose above seven in a hundred, or one in fourteen. In like manner, a mixture of gold with half its weight of silver will be found to lose one part in  
fifteen

fifteen and four tenths; with a third of silver, one in sixteen and two tenths; with a fourth, one in sixteen and seven tenths; and with an eleventh of silver, which is the standard proportion of alloy, one in eighteen and one tenth. On this principle, the specific gravity, or proportional loss in water, of gold alloyed with different quantities of silver, copper, and mixtures of both, may be computed, and formed into tables, for abridging the trouble of calculation in the trial of given masses.

A person, said to have made large profits in the purchase of gold from the Chinese, made use of this method for estimating the fineness of the gold. With the assistance of tables, now in my hands, he could readily determine by the balance the quality of the whole compound, or the quantity of fine gold it contained; without any danger of being imposed on by a superficial coat, however thick, or by any baser materials, that were there known, being included within the mass. The Chinese alloy being, as already observed, almost always silver, contributed not a little both to the facility and accuracy of the examination.

The above method of calculation supposes, that when the two metals are melted together, each of them still retains its own proper gravity, as if they were joined only by simple apposition. In mixtures of gold with silver, this appears to be the case, but in mixtures of it with other metals there are some variations. Gold and copper, melted together, prove specifically lighter, or lose a greater proportion of their weight in water, than if they were weighed separately: Mr. Gellert, in a treatise of metallurgic chemistry published in 1750, observes, that the same thing happens in mixtures of gold with zinc, tin, and iron; but the reverse in mixtures of it with lead and bismuth. In some of the compositions of gold with platina, a dilatation of the volume (whence necessarily  
results



results a diminution of the specific gravity, or of the weight under an equal volume) is apparent to the eye; the mixture, in its return from a fluid to a solid state, instead of shrinking and becoming concave, expanding and becoming convex. Platina, purified by solution in aqua regis and precipitation with quicksilver, being melted with twice its weight of fine gold, and the fusion repeated upwards of twelve times successively, the surface of the mass, when cold, was every time convex: the gold being gradually increased, the convexity continued sensible till the quantity of gold was upwards of ten times greater than that of the platina; but when the gold was in very large proportion, the mixture shrank and became concave like pure gold.

From these dilatations and contractions of volume, which happen in different mixtures, it may be presumed, that the hydrostatic balance cannot discover, with certainty, the exact fineness of gold, unless when silver is the metal mixed with it. When the alloy is copper, some allowance must be made, not only for the diminution of gravity arising from mixture, but likewise for the differences in the gravity of copper itself, that of some sorts being about nine, and that of others, though seemingly of equal fineness, scarce eight and three fourths. When gold is alloyed with both copper and silver, though the foregoing causes had no influence, the quantity of gold could not be found to any exactness unless the proportions of copper and silver to one another were known.

## S E C T. VIII.

### *Of the assaying of gold.*

**T**H E quantity of gold allowed for an assay is among us six grains; in France, as we learn from Hellot, nearly the same; in Germany, according to Schlutter, about

about three times as much. It is evident that great nicety is requisite, in regard both to the weights, and the conduct of every part of the operation, where the value of a large mass of gold is to be determined by an experiment on so small a quantity. Care must be taken also that the portion to be assayed is of equal fineness with the rest of the mass: we have already seen that the alloy may in some cases be unequally distributed in fusion, and the upper and lower parts of the mixt prove different in richness: in large ingots or pieces of cast gold, a little should therefore be collected from the bottom, and a little from the top, so as to obtain a mixt corresponding as nearly as may be to the quality of the whole mass.

The assaying of gold consists of two processes; one for separating it from silver, the other from base metals. The separation of silver from gold is effected by aqua fortis, which dissolves the silver, and leaves the gold entire behind: but that this separation may succeed, it is necessary that the mixt contain considerably more silver than it does gold; for otherwise the particles of silver are enveloped by the gold, and defended from the action of the acid. Some judgement must therefore be previously formed of the contents of the mass, from its colour on the touchstone or by the hydrostatic balance: if it appears to be about the standard fineness, it is melted with about twice its weight of silver: if it is finer, a little more silver is added, and if coarser less; so that the alloy and additional silver together may always amount to somewhat more than twice the quantity of the gold. The writers on assaying in general direct three parts of silver to one of gold: but a less proportion is found to be sufficient, and more than is sufficient should never be used, for reasons which will appear in the sequel of the process.

The separation of base metals is effected, by keeping the mixt in fusion for some time upon a cupel with the addition of lead. The lead by degrees turns to a scoria or dross, which rising to the surface and liquefying, looks like oil, and is no longer miscible with any metallic body in its perfect metallic state: all the metals, silver and platina excepted, change into dross, and separate from the gold, along with the lead. As silver stands this operation, equally with gold itself, the gold and the additional silver are submitted to it together: and indeed though there was no base metal to be separated, the little quantities of gold and silver employed for an assay, are more commodiously mixed, form a neater bead, and with less danger of loss, upon a cupel with a little lead, than by fusion in a crucible. It is obvious that both the silver and lead ought to be pure from any admixture of gold.

### I. *Cupellation with lead.*

THE cupel is a small vessel, which absorbs metallic bodies when changed by fire into a fluid scoria, but retains them so long as they continue in their metallic state. One of the most proper materials, for making a vessel of this quality, is the ashes of animal bones: there is scarcely any other substance, which so strongly resists vehement fire, which so readily imbibes metallic scoriæ, and which is so little disposed to be vitrified by them. In want of these, some make use of vegetable ashes, freed, by boiling in water, from their saline matter, which would occasion them to melt in the fire.

The bones, burnt to perfect whiteness, so as that no particle of coaly or inflammable matter may remain in them, and well washed from filth, are ground into moderately fine powder, which, in order to its being formed

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into cupels, is moistened with just so much water as is sufficient to make it hold together when strongly pressed between the fingers; some direct glutinous liquids, as whites of eggs or gum water, in order to give the powder a greater tenacity: but the inflammable matter, however small in quantity, which accompanies these fluids, and which cannot easily be burnt out from the internal part of the mass, is apt to revive a part of the metallic scoria that has been absorbed, and to occasion the vessel to burst or crack. The cupel is formed in a brass ring, from three quarters of an inch to two inches in diameter, and not quite so deep, placed upon some smooth support: the ring being filled with the moistened powder, which is pressed close with the fingers, a round-faced pestle, called a monk, is struck down into it with a few blows of a mallet, by which the mass is made to cohere and rendered sufficiently compact, and a shallow cavity formed in the middle: the figure of the cavity is nearly that of a portion of a sphere, that a small quantity of metal, melted in it, may run together into one bead. To make the cavity the smoother, a little of the same kind of ashes, levigated into an impalpable powder, and not moistened, is commonly sprinkled on the surface, through a small fine sieve made for this use, and the monk again struck down upon it. The ring or mould is a little narrower at bottom than at top, so that by pressing it down on some of the dry powder spread upon a table, the cupel is loosened and forced upwards a little, after which it is easily pushed out with the finger, and is then set to dry in a warm place free from dust.

Another kind of vessel is required in cupellation, called a muffle, formed of any clayey earth that will bear a strong fire, with a flat bottom, arched at top, and open in the front: it is made nearly of a semicylindrical figure, its

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length

length about double to its height, and the height somewhat less than the width of the bottom. This is placed upon a grate, in a proper furnace, such as that described in page 12 and 35, with its mouth facing the door, and fitting as close to it as may be. The furnace being filled up with fuel, some lighted charcoal is thrown on the top, and what fuel is afterwards necessary is supplied through a door above. One or more cupels are set in the muffle, and being gradually heated by the successive kindling of the fuel, they are kept red hot for some time, that the moisture, which they strongly retain, may be completely dissipated; for if any vapours should issue from them after the metal is put in, they would occasion it to sputter, and a part of it to be thrown off in little drops. In the sides of the muffle are some perpendicular slits, with a knob over the top of each to prevent any small pieces of coals or ashes from falling in. The door, or some apertures made in it, being kept open, for the inspection of the cupels, fresh air enters into the muffle, and passes off through these slits: by laying some burning charcoal on an iron plate before the door, the air is heated before its admission; and by removing the charcoal, or supplying more, the heat in the cavity of the muffle may be somewhat diminished or increased, more speedily than can be effected by suppressing or exciting the fire in the furnace on the outside of the muffle. This renewal of the air is necessary also for promoting the scorification of the lead.

The cupel being of a full red heat, the lead cast into a smooth bullet that it may not scratch or injure the surface, is laid lightly in the cavity: it immediately melts, and then the gold and silver are cautiously introduced, either by means of a small iron ladle, or by wrapping them in paper and dropping them on the lead with a tongs. The

quantity of lead should be at least three or four times that of the gold : if the gold is very impure, ten or twelve times its quantity will be necessary. It is reckoned that copper requires for its scorification about ten times its weight of lead ; that when copper and gold are mixed in equal quantities, the copper is so much defended by the gold, as not to be separable with less than twenty times its quantity of lead ; and that when the copper is in very small proportion, as a twentieth or thirtieth part of the gold and silver, upwards of sixty parts of lead are necessary for one of the copper. The cupel must always weigh at least half as much as the lead and copper, for otherwise it will not be sufficient for receiving all the scoria : there is little danger however of cupels being made too small for the quantity of a gold assay.

The mixture being brought into thin fusion, the heat is to be regulated according to the appearances, and in this consists the principal nicety in the operation. If a various-coloured skin rises to the top, which liquefying runs off to the sides, and is there absorbed by the cupel, visibly staining the parts it enters ; if a fresh scoria continually succeeds, and is absorbed nearly as fast as it is formed, only a fine circle of it remaining round the edge of the metal ; if the lead appears in gentle motion, and throws up a fume a little way from its surface ; the fire is of the proper degree, and the process goes on successfully.

Such a fiery brightness of the cupel as prevents its coloured parts from being distinguished, and the fumes of the lead rising almost up to the arch of the muffle, are marks of too strong a heat ; though it must be observed, that the elevation of the fumes is not always in proportion to the degree of heat, for if the heat greatly exceeds the due limits, both the fumes and ebullition will  
entirely

entirely cease. In these circumstances, the fire must necessarily be diminished: for while the lead boils and smokes vehemently, its fumes are apt to carry off some part of the gold, the cupel is liable to crack from the hasty absorption of the scoria, and part of the gold and silver is divided into globules, which lying discontinued on the cupel after the process is finished, cannot easily be collected: if there is no ebullition or fumes, the scorification does not appear to go on. Too weak a heat is known by the dull redness of the cupel, by the fume not rising from the surface of the lead, and the scoria like bright drops in languid motion, or accumulated and growing consistent all over the metal. The form of the surface affords also an useful mark of the degree of heat; the stronger the fire the more convex is the surface, and the weaker the more flat: in this point however regard must be had to the quantity of the metal, a large quantity being always flatter than a small one in an equal fire.

Towards the end of the process, the fire must be increased; for greatest part of the fusible metal lead being now worked off, the gold and silver will not continue melted in the heat that was sufficient before. As the last remains of the lead are separating, the rainbow colours on the surface become more vivid, and variously intersect one another with quick motions: soon after, disappearing all at once, a sudden luminous brightness of the button of gold and silver shews the process to be finished. The cupel is then drawn forwards, towards the mouth of the muffle; and the button, as soon as grown fully solid, taken out.

It is observable, that when fine gold is thus cupelled with lead, it retains always a portion of the lead, very minute indeed, but sufficient to render it pale and brittle. Ercker endeavours to prevent this inconvenience, by patting the cupel with the tongs, so as to produce a tremulous

lous motion in the gold just before it hardens ; but though this practice may be of use in some cases, it cannot procure a total separation of the lead, when the gold has no other admixture. Mr. Scheffer observes, in the transactions of the Swedish academy for the year 1752, that if the gold is mixed with a little copper, as one twenty-fourth of its weight, it parts in cupellation with all the lead, and retains nearly all the copper ; that if a small proportion of silver be superadded, greater than that of the copper, it contrariwise parts with the copper, and retains a little of the lead ; but that if the quantity of silver is nearly equal to, or greater than, that of the gold, as in the present process, both the copper and lead may be completely worked off, and only the gold and silver left.

The metal principally intended to be separated by cupellation is copper. If the gold contained any tin, the process does not succeed well, the tin calcining with a part of the lead, and rising up in a powdery or spongy mass, which is apt to retain a part of the gold, and which cannot easily be made to melt, the calx of tin being extremely refractory. In this case, which rarely occurs to the assayer, the addition of a little iron filings is of use ; the tin having a strong affinity to iron, and forming with it a new compound, which works off pretty freely with the lead.

Though the lead continues to emit fumes during the cupellation, yet little of its substance is dissipated. The cupel, after it has absorbed the scoria of the lead, weighs as much as the cupel and lead did at first ; and even more, metallic bodies being found to gain weight in their scorification. Several experiments of this kind, made at the Tower by the direction of lord Brouncker, are inserted in Sprat's history of the royal society : when lead, or a mixture of lead and copper, were worked off in a cupel, there



there was always an increase of weight, though not quite so great as lead commonly acquires in the process of slow calcination.

## II. *Parting with aqua fortis.*

AQUA FORTIS is an acid spirit prepared from nitre by the intervention of other bodies. The principle, on which the extraction of the acid depends, has been but lately understood; and hence in the earlier writers on these subjects, as Ercker and Agricola, we meet with many incongruous compositions; some containing powdered flint, sand, and other ingredients which serve only to take up room in the distilling vessel; some, quicklime, which can do no more, than to lessen the produce of acid, by absorbing and detaining a part of it; and some, common salt, whose acid, mingling with the nitrous, forms with it a menstruum of a quite different nature from that here required. What is wanted is the pure acid of nitre; and the extrication of this, from the alkaline basis of the nitre, is effected by the acid of vitriol.

Those, who prepare aqua fortis in quantity, use frequently green vitriol uncalcined or undried. This method is accompanied with two capital inconveniences: the watery parts, which the vitriol abounds with, being expelled first by the heat, together with a portion of the acid, this part of the vitriolic acid is thus so far diluted, as not to act sufficiently upon the nitre, and rising over into the receiver, souls the aqua fortis that succeeds: at the same time the vitriol, which at first liquefies in the vessel along with the nitre, concretes, on the dissipation of its watery moisture, into a hard mass, from which the full quantity of acid cannot be forced out by any violence of fire.

The more judicious workmen calcine the vitriol, before its mixture with the nitre, till it is freed from its phlegm,  
and

and will no longer liquefy in the fire. For this purpose, a quantity of the vitriol may be put into an iron pot, such as one of those which are used as sand-pots for the portable furnaces already described: The vessel is set over a gentle fire, which is gradually increased when the vitriol melts, till the matter thickens again, and acquires an ash grey colour: the vitriol is to be constantly stirred, till it becomes dry and powdery, and is then to be taken out whilst hot; for if suffered to cool in the vessel, without stirring, it concretes so hard, as scarce to be beaten off with a hammer. Some calcine the vitriol in an earthen pan: the pan is at first about half filled, and when this has sunk down, and incrustated about the sides, more is added, till the vessel is full, which must afterwards be broken for getting the matter out.

Eight pounds of vitriol thus calcined to about four, and three pounds of nitre made likewise very dry, are to be reduced separately into very fine powder, and thoroughly mixed together. The mixture is to be put into the same iron pot in which the vitriol was calcined, a stone-ware head with a large glass receiver fitted to it, and the junctures luted with Windsor loam, or a mixture of clay and sand, beaten up with some cut tow, and moistened with a solution of fixt alkaline salt. In the receiver may be placed a pint of water, which will promote the condensation of the nitrous fumes, without rendering the acid too dilute for the purposes which it is here designed for. During the distillation, there arises a quantity of elastic vapour, which must be suffered to escape, as it would otherwise either force the luting, or burst the receiver. The most convenient way of procuring an outlet for it, without endangering any loss of the acid, appears to be, by making a hole in that part of the receiver which is to be placed uppermost, and inserting into it a slender glass pipe,

pipe, four feet long or more, which is to be secured by the same lute as the juncture of the head and receiver: the pipe allows a free passage to the air or unconfinable vapours, while little or nothing of the more sluggish acid fumes will arise so high. The hole in the receiver may be made, by pasting on it a piece of thick leather, having a hole of the intended size cut in it, then filling the cavity with emery, and turning round in it a steel instrument, with a hollow in the point for retaining the emery, till the glass is worn through.

A gentle fire being made under the pot, the receiver soon grows warm, and appears covered with dewy drops, which are the more watery part of the mixture. The receiver beginning to grow cool again, the fire is to be gradually increased, till yellow or reddish fumes appear, and when these cease, it is to be further urged by degrees, till the pot becomes red hot, and nothing more can be forced over.

This process is nearly the same with that commonly followed in the way of business; differing little otherwise than in the size of the vessels, and the quantity of the materials used at once. But as the effect of the vitriol depends wholly upon its acid, and as the acid of sulphur is the same, and is now to be procured at a very cheap rate, the most advantageous way of making spirit of nitre or aqua fortis is, to use the acid spirit instead of vitriol. Two pounds of oil of vitriol are to be mixed with an equal quantity of water, in a stone-ware vessel, by a little at a time; for if the acid is added all at once to the water, the mixture becomes so hot, as to be apt to make the vessel crack. Three pounds of nitre being put into a glass retort, the mixture is to be poured on it through a long-necked funnel, that none of the vitriolic acid may adhere to the neck, and foul the nitrous spirit as it di-

stils. The retort being placed in an iron pot on a little sand, and a receiver with its upright pipe luted on, the fire is to be gradually increased, so long as any red fumes arise, or any drops fall from the neck of the retort.

In either of these methods, a portion of the vitriolic acid frequently rises along with the nitrous; and frequently also, as nitre has often an admixture of sea salt, the distilled spirit partakes of marine acid. If a piece of silver be put into this impure aqua fortis, some part of the silver will be dissolved by the nitrous acid, but the other acids will immediately seize it, and form with it an indissoluble white powder. For this use therefore, the aqua fortis must be previously purified from these extraneous acids: and their property of uniting with and precipitating dissolved silver affords a commodious and effectual means of its purification. A little solution of silver, already made, is dropt at intervals into a quantity of the aqua fortis; which, if it contains any marine or vitriolic acid, becomes instantly milky: when the addition of a fresh drop or two of the solution occasions no further milkiness or cloudiness, we may be sure that those acids are completely absorbed by the silver: the whole is suffered to stand till the white matter has perfectly settled to the bottom, and the clear liquor is then poured off. The solution of silver, from its carrying down, and fixing as it were, the heterogeneous acids, is called by the workmen *fixes*.

Care must be taken also that the common water, made use of in the process of parting, have no impregnation that would impede the dissolution of silver, or precipitate it when dissolved. Spring waters have generally such an impregnation, most of them producing a strong milkiness with solution of silver: rain water, collected with proper care, is for the most part sufficiently pure, as is likewise  
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that of most rivers, though the preference is always to be given to such as has been distilled. Those waters, which turn milky with solution of silver, may be made fit for this use, in the same manner as the impure aqua fortis, by dropping in a little of the solution, till all the matter, that is capable of precipitating the silver, is separated: in this case, great care must be taken, not to use more than is necessary of the solution; for so much of the dissolved silver, as is added after the marine and vitriolic acids have satiated themselves, will continue dissolved in the water; and as the gold is at last to be washed in the water, the moisture, that hence adheres to the gold, containing a proportionable part of the dissolved silver, will on drying leave it in the gold.

Besides the purity of the aqua fortis, a good deal of caution is requisite in regard to its strength. The only sure mark of its due strength, for the parting assay, is its effect in the process itself; and the manner of adjusting it will be the more intelligible after the process has been described.

The little bead of gold and silver, remaining after the cupellation, is carefully hammered a little, and passed several times between polished steel rollers, screwed gradually closer and closer, till it is extended into a very thin plate, which is coiled up into a spiral form, so as that the several circumvolutions may not touch one another: by this means it lies in a small compass, so as to be covered by a quantity of aqua fortis sufficient for dissolving the silver, and yet exposes a large surface to the action of the dissolvent. The metal is now and then nealed during the flattening; and after this part of the process is finished, it is again made red hot, both to burn off any unctuous matter that may have adhered to it, and to soften the silver, which in this state is supposed

to yield more easily to the menstruum. The coiled plate is put into a small glass vessel, called a parting glass, broad at the bottom and tapering upwards; with twice its weight or more of the prepared aqua fortis. The vessel is set in a sand-bath or other moderate heat, not exceeding that of boiling water; and its mouth stopp'd lightly with paper, or covered with a plate of glass, so as to keep out dust, without preventing the escape of the elastic vapours which rise during the dissolution. So long as the acid continues to act, the metal appears every where encompassed with minute bubbles, which issue from it in jets: the disappearance of these, or their uniting into a few large ones, is a mark that the acid is fatigued.

The coiled plate, after the silver is thus eaten out from it, should still retain its original form: for if the gold falls into powder, it can scarcely be collected without the loss of some particles, which, though small in bulk, may amount to a considerable proportion of the little quantity of metal made use of. This cohesion of the gold depends, partly, upon the quantity of silver not being so large as to leave the golden particles discontinued; and partly on the action of the acid not being so violent, as to divide and disunite the gold by its impetuous extraction of the silver. The strength of the acid is to be ascertained by previous trials on gold and silver mixed together in the assay proportions: if it is found to disunite the gold, it must be lowered with water till it leaves the plates entire. These trials are to be made exactly in the same manner as the assay process itself.

The liquor is poured off whilst hot, lest some of the dissolved silver should crystallize in cooling upon the remaining gold. To the golden plate, which appears spongy and of a dark reddish brown colour, a little fresh  
aqua

aqua fortis is added, and heated more considerably than before, to extract what silver may still be left in it ; this may be repeated a second or a third time ; after which some water is poured on, and renewed two or three times, to wash off the saline matter. The parting glass being then full of water, a small gold vessel (a silver one will do) is applied closely on its top ; and both being nimbly inverted, and the parting glass carefully raised a little at one side, the golden plate is washed down into the lower vessel : if this last is insufficient for receiving all the water, the glass is to be lifted up a little, so as that the thumb or a piece of stiff paper can be applied to its orifice under the water, after which it may be removed without disturbing the liquor, or damaging the brittle plate. The water being poured off, the plate is dried, and gradually heated till the gold resumes its proper colour, which happens soon after its becoming red hot. Some make use of an earthen crucible ; but in this case, small particles of the earth are apt to adhere imperceptibly to the gold, whence the assay becomes less certain.

If the gold, after having passed through these operations, is found to be of the same weight as at first, it is reputed nearly fine, but not entirely so : for the aqua fortis leaves always in the gold a small portion of the silver, amounting commonly to above a three hundredth, and sometimes to a hundredth part of its weight ; whence, if the gold was at first fine, it will in this process receive an increase. If it is required to determine exactly the proportion of this increase, it may be done by submitting to the same operation an equal quantity of gold known to be fine, mixed with the same proportion of silver. The differences in the quantity of silver, thus left in the gold, are supposed to proceed from unheeded differences in the quality of the aqua fortis, particularly in its strength ; so  
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that the assayer ought to examine in this view each parcel of aqua fortis he employs, and deduct, from the weight of the gold remaining in the assay, the proportion of silver which that particular aqua fortis is found to leave.

The assayer's report, of the fineness of the gold which he has examined, expresses the number of carats, with the odd grains or fourths of a carat, and quarters of these, by which it is finer or coarser than the standard. Thus standard gold being of twenty-two carats, that is, twenty-four parts of it losing two in the purification; if the mass assayed lose one less, it is reported *B. 1 car.* or one carat better; and if it loses one more, it is reported *Wo. 1 car.* or one carat worse.

By these processes gold is separated from all the known metallic bodies, platina excepted: if any of this was mixed with it, nearly the whole of the platina will still remain, not destructible by the lead, and not dissoluble by the aqua fortis. If the quantity of platina is considerable, it may be distinguished by the brittleness and ill colour of the mixt: but there are proportions of it, not sufficient to sensibly affect the gold in these respects, though they may nevertheless deserve regard. If the gold is suspected to be thus debased, the abuse may be discovered by the following means.

After the golden plate has been weighed, and its fineness determined in the common method, a part of it is to be dissolved in a little aqua regia, and a filtered colourless solution of any fixt alkaline salt gradually dropt into the liquor, so long as it occasions any turbidness or precipitation: all the gold will fall to the bottom, with a part of the platina, but so much of the platina will continue dissolved, as to discover itself by communicating a yellow tinge. This intention may be answered still more effectually by the æther, which imbibing the gold, and carrying



ing it up to the surface, leaves the full quantity of the platina to shew its colour in the acid liquor. By this method, a most minute proportion of platina may be distinguished, a little of this metal giving a high colour to a surprizingly large quantity of the menstruum.

The method of preparing the æther is described by many chemical writers, but the most safe, easy, and certain process I have met with, is that which Dr. Morris has favoured the publick with in the medical observations and inquiries of a society of physicians in London. Nine parts by weight of oil of vitriol are poured, by two ounces at a time, at intervals of a quarter of an hour, into eight parts by weight of rectified spirit of wine, in a large stone bottle: after standing for a night, the mixture is decanted from one vessel to another three or four times, and then conveyed, through a long-necked funnel, into a retort capable of containing three times the quantity. The retort is set on a little sand in an iron pot, and more sand put round it up to the height of the mixture: a larger receiver being luted on, with some strips of wet bladder, a small hole is made in the luting with a pin: the fire is raised somewhat hastily, till an ebullition accompanied with large bubbles is observed in the mixture; after which the fire is to be entirely removed, the heat of the sand being sufficient for completing the distillation. The distilled liquor is put into a clean retort, with two or three ounces of fixt alkaline salt: about half the liquor is drawn off, by a very gentle heat, into a large receiver; and this being shaken with an equal quantity of pump water, the pure æther rises immediately to the top.

## S E C T. IX.

*Of the refining of gold ; and the separation of small portions of gold from other metals.*

*I. Separation of gold from base metals by testing with lead.*

**T**HE processes described in the preceding section, for the assaying of gold, are used also for refining it in the way of business ; with such variations, in the manner of conducting them, as the greater quantities operated upon, and the requisite cheapness and dispatch, render necessary.

The test is a large kind of cupel, formed of the same materials with the small ones. Some of the German writers recommend, both for tests and cupels, a sort of friable opake stone, called white spath, which appears to be a species of gypsum, or of the stones from which plaster-of-paris is prepared. The spath is directed to be calcined with a gentle fire, in a covered vessel, till the slight crackling, which happens at first, has ceased, and the stone has fallen in part into powder : the whole is then reduced into subtile powder, which is passed through a fine sieve, and moistened with so much of a weak solution of green vitriol, as is sufficient for making it hold together : Gellert however finds, that if the stone is of the proper kind, which can be known only by trials, calcination is not necessary. Scheffer observes, that these kinds of tests are liable to soften or fall asunder in the fire, and that this inconvenience may be remedied, by mixing with the uncalcined stone somewhat less than equal its weight, as eight ninths of such as has been already used and is penetrated by the scoria of the lead, taking only that part of the old test which appears of a green-grey colour, and rejecting the red crust on the top. Tests or cupels made of the spath are said not to

require so much caution, in melting and heating them, as the common ones: it appears however from Scheffer's account, that they are less durable than those made of the ashes of bones, though greatly superior to those of wood ashes. Vegetable ashes, which stand pretty well the testing of silver, can scarcely bear any great quantity of gold, this metal requiring a considerably stronger fire than the other: but bone ashes answer so effectually, and are among us so easily procurable, that it is not needful for the refiner to search for any other materials; though those who work off large quantities of lead, in order to gain a little silver or gold contained in it, may possibly, in places remote from populous cities, avail themselves of substances similar to the spath above mentioned.

The test, for its greater security, is kept fixed in the mould in which it was formed; which is sometimes a shallow vessel made of crucible earth or cast iron, more commonly an iron hoop, with three bars arched downwards across the bottom, about two inches deep, and of different widths, from three or four inches to fifteen or more, according to the quantity of metal to be tested at once. The ashes or earthy powder, moistened as for making cupels, are pressed down in the mould so as to completely fill it or rise a little above the sides; with care to make the mass equally solid, and to put in at once, or at least after the bottom has been pressed close, as much of the matter as will be sufficient for the whole, for any additional quantity will not unite thoroughly with the rest, but be apt to part from it in the fire. The edges are pared smooth, and a portion cut out from the middle with a bent knife, so as to leave a proper cavity, which is smoothed by strewing some dry powder on the surface, and rolling on it a wooden or rather a glass ball.

The process of testing is often performed in the same manner as that of cupellation : but where great quantities of base metal are to be worked off from a little gold, recourse is had to a more expeditious method, that of testing before the bellows.

An oval test is placed in a cavity, made in a hearth of a convenient height, and some moistened sand or ashes pressed round it to keep it steady : the nose of a bellows is directed along its surface, in such a manner, that if ashes are sprinkled in the cavity of the test, the bellows may blow them completely out : some have an iron plate fixed before the bellows, to direct the blast downwards. To keep the surface of the test from being injured in putting in the metal, some clothes or pieces of paper are interposed. The fuel consists of billets of barked oak, laid on the sides of the test, with others laid crosswise on these : the bellows impels the flame on the metal, clears the surface of ashes or sparks of coal, hastens the scorification of the lead, and blows off the scoria, as fast as it forms, to one end of the test, where it runs out through a notch made for that purpose. About two thirds of the scorified lead may thus be collected, the rest being partly absorbed by the test, and partly dissipated by the action of the bellows. Care must be taken not to urge the blast too strongly, lest some portion of the gold should be carried away by the fumes impetuously forced off from the lead, and some minute particles of it entangled and blown off with the scoriæ.

In the history of the French academy of sciences for the year 1727, a process is given for purifying a particular kind of debased gold, which is said to be quite brittle and intractable, not to flow thin enough to be poured completely out of the crucible, to appear on the surface of a livid hue, and which is supposed by du Fay and Hellot to receive

receive these imperfections from an admixture of emery. The gold is to be melted with equal its weight of bismuth, and so much poured out as is fluid enough to run : to the remainder is to be added equal its weight more of bismuth, and this procedure repeated till the whole of the gold has run thin from the crucible. The mixt is put into a large thick cupel or test, included in a mould of crucible earth ; by a suitable fire, the bismuth works off as lead does, leaving the gold still impure and covered with a livid skin. For every eight ounces of gold, two or three ounces of lead are then to be added, and the fire continued till the lead is worked off : the gold is still found not sufficiently fine, though less brittle and less livid than it was before. It is now to be melted in a forge or blast furnace, and the flame impelled by the bellows upon the surface of the metal, till it begins to grow clear ; after which the repeated injection of some mercury-sublimate, with a little borax towards the end, completes the purification.

I have not had an opportunity of examining this process, having never met with any gold that had the characters of impurity above described, except such as was mixed with platina, which I did not find to be benefited by this treatment.

## II. *Separation of gold from silver by aqua fortis.*

PARTING with aqua fortis is one of the most common operations, both for purifying gold from a little silver, and for extracting a little gold from a large proportion of silver. Frequently both intentions are answered at once : for when gold is thus to be purified, it requires, as we have already seen, an addition of silver, and such silver as contains gold is always preferred for this use ; so that

the gold is got out from the silver, without any additional expence, in the same operation by which the other gold is refined.

The most desirable proportions of the two metals are, one part of gold to three of silver, or one part of gold in four of the mixt, whence the process is sometimes called quartation. When silver is added to gold, merely with a view to the purifying of the gold, these proportions should be kept to, as nearly as may be: for if the quantity of silver is less, the dissolution of it will not go on with sufficient dispatch; and if greater, it will occasion an unnecessary expence of acid. Silver containing only a small portion of gold is frequently submitted to this operation: but in such cases, there are less expensive methods, which will be described in the sequel of this section, for separating great part of the silver, so as to leave only a moderate quantity to be dissolved by the aqua fortis.

The metal, instead of being flatted into plates, as for the parting assay, is reduced, with less trouble, into small grains, by melting it in a crucible, and pouring it into cold water. Some interpose a number of twigs, or a birch broom, wetted, between it and the water, to divide the fluid metal into slender streams: Cramer describes a machine for this purpose, composed of a wooden roller, laid across the vessel of water, with its lower surface touching the water, covered all over with twigs, and made to turn by a handle. The granulation may be performed very successfully without any contrivance of this kind, by nimbly stirring the water round, so as to communicate to it a rapid circular motion, and pouring in the metal at one side.

The granulated metal, with a suitable quantity of aqua fortis, is put into parting glasses, which are commonly about twelve inches high, seven inches wide at the bot-

tom, and tapering upwards: several of these vessels are placed along an iron range covered with sand to the thickness of about two inches. Great care should be taken that the glass be well nealed, as equal as may be in thickness, and free from blebs, for otherwise it generally cracks in the process. The aqua fortis must be purified as for the parting assay, though it is not needful to be so curious in adjusting its strength: it ought to be strong enough to begin to act sensibly on silver in the cold, and not so strong as to act with violence.

A gentle fire is made under the sand bath, which is increased or diminished, according as the dissolution appears to proceed slowly or hastily. Care must be had not to apply too much heat at the beginning, the liquor being very liable to swell up and run over the vessel; but towards the end, when most of the silver is dissolved, and the acid nearly fatiated, there is no danger of this accident. When the menstruum has ceased to act, which is known by its growing clear, and no more air bubbles rising in it, the solution is poured off; and if, on stirring the remaining matter, any grains are perceived in it, a little more aqua fortis is added, to complete the extraction of the silver: some use a smooth wooden rod for the stirring, and what dissolved silver the wood imbibes, they recover by burning it. The blackish mud, into which the gold is reduced by the dissolution of the silver from it, is washed five or six times with water, and afterwards melted.

One of the principal inconveniencies, attending this operation, is, that the parting glasses are extremely liable to crack, from the contact not only of a cold body, but even of the hand. Schlutter reports, that in the Hungarian refineries, where great quantities of gold-holding silver are parted, the glasses are secured by a strong coating, up  
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to such a height, as not to hinder the operator from observing how the dissolution goes on: some quicklime, flaked with beer, and mixed with whites of eggs, is spread on a linen cloth, which being wrapped round the glass, a composition of clay and hair is applied over it. He gives also a contrivance of his own, which he seems to have introduced into the works of the lower Hartz, for preserving the dissolved silver, as well as the gold, when the glasses happen to break, or the liquor to run over. His parting glasses are fifteen inches high, ten or twelve inches wide at the bottom, and at the top about as wide as the mouth of a common bottle: for each of these he has a copper pan, twelve inches wide at bottom, fifteen at top, and ten in height, which stands on a trevet, with some charcoal under it: some water is put into the pan, and two pieces of wood placed crosswise in its bottom, as a support for the glass, to prevent it from hitting against the copper. Into one of these glasses he puts about eighty ounces of gold-holding silver, with twice as much aqua fortis, without danger of any loss though the glass should break: the heat may likewise be speedily diminished, if the acid should act too impetuously, by pouring cold water into the pan. Great care must be taken in the addition of the cold water: it should be poured against the sides of the pan, and stirred with the rest, that it may be equally mixed before it reaches the glass.

The silver is recovered from its solution by means of copper. The solution, diluted with water, being put into a copper vessel, or into a glass one along with copper plates (the refiners use commonly a wooden bowl-dish lined with copper) the silver begins immediately to separate from the liquor in form of fine grey scales or powder; a part of the copper being dissolved in its place, so as to tinge the fluid more and more of a blue colour. The plates



plates are now and then shaken, that such part of the silver as is deposited upon them, may fall off and settle to the bottom, for otherwise the copper would be defended by it from the acid, and the precipitation of the silver would not go on. The digestion is continued, till a fresh bright copper plate, kept for some time in the hot liquor, is no longer observed to contract any powdery matter upon the surface : the liquor is now poured off, the precipitated silver washed with fresh portions of boiling water, and afterwards melted with nitre to scorify such particles of the copper as have fallen with it. Without the assistance of heat, the precipitation is scarcely completed in seven or eight days : Schlutter observes, that the dispatch requisite for business, can scarcely be obtained without a boiling heat. Great part of the silver indeed soon separates, but in proportion as the acid loads itself with the copper, its action becomes more and more languid, and is at length so weak, that some small portion of the silver is frequently at last retained : this may be discovered by adding to a portion of the solution a drop or two of a solution of common salt : if the liquor contained any silver, it will grow turbid on this addition, and deposit the silver combined with the acid of the common salt. I have been sometimes surprized to find copper plates produce no precipitation at all in solution of silver : this happened when the menstruum was loaded with as much silver as it could be made to dissolve ; and on adding a drop or two of fresh acid, the precipitation went on as usual.

From the solution of copper is prepared a blue pigment called verditer, by which the expence of refining is lessened. According to Dr. Merret's account, a quantity of whiting is put into a tub, the copper solution poured on it, and the mixture stirred every day for some hours together, till the liquor loses its colour, the copper being deposited

in the whiting, and a part of the whiting taken up in its room. The liquor is then poured off, more of the copper solution added, and this repeated, till the matter appears of the due colour, after which it is spread on large pieces of chalk, and laid in the sun to dry. Boyle observes that the process often miscarried, and that heating the liquor before it is poured on the whiting, has been found to contribute to its success. It is still however, as I am informed, very apt to fail, in the hands of the most skilful workmen, the preparation, instead of a fine blue, turning out of a dirty green.

From the liquor poured off in making verditer, consisting of the nitrous acid saturated with the whiting, great part of the acid is recovered, by evaporating the watery part, and adding the remaining thick matter in the distillation of the next quantity of aqua fortis. The acid may be extracted also either from the solution of copper or silver, and the metals recovered, the silver by fusion without any addition, the copper by the addition of inflammable matter. The following process is given for this purpose in the French memoirs for the year 1728, as the communication of an experienced artist.

The copper solution is put into a copper vessel placed in a furnace, and evaporated to about half: the vessel is then filled up with more of the liquor, and the evaporation continued till the fumes begin to smell of aqua fortis. The acid, being already satiated with copper, does not act on the vessel, or so little, that du Fay says he has seen one vessel bear almost constant work for near a year: the vessel should be raised out of one plate, not formed of pieces, for if it is rivetted or soldered, the liquor will soon make its way through the junctures, as I have often observed in this and other solutions of the same kind. On decanting off the liquor, a portion of silver is found at  
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the bottom, which the acid had before retained, and which the long boiling has disengaged. Stone ware cucurbits, coated with lute, are charged with the liquor to about two thirds of their height : the French have a kind of ware (*pots de grais*) which is said to answer extremely well for this use : such of our common stone wares as I have formerly tried, frequently failed. Five or six of these vessels are let into one furnace, up to the height of the liquor, and the bottoms made to rest on iron bars : the furnace is long and narrow, with a door at one end for putting in the fuel, and the chimney at the other. On each jar is luted a stone ware head with two spouts and receivers. The fire is raised to such a degree as to make the distillation go on with sufficient dispatch, with care only not to increase it so far, as to endanger the matter swelling up into the head. When about three fourths have come over, the fire is suffered to decay, and the vessels to cool, that the heads may be unluted, and more of the copper solution poured in. This is repeated three or four times, till it is judged that the calx of copper in each jar rises to about a fourth of its height, after which the fire is strongly urged, till the bottoms of the jars become red hot, and nothing more will distil. This troublesome process might be improved by substituting to the cucurbits the copper pan in which the evaporation is performed ; which may be converted into a distilling vessel, by fitting to it a stone-ware breast and head, in the same manner as the copper breast and head are fitted to the still in the first plate : there is no occasion for two spouts, as one, of a proper width, will supply the place of the two : the copper pan should be let into the furnace almost to its upper edge ; and the breast should enter the pan nearly to the surface of the liquor. The aqua fortis thus ob-

tained is perfectly free from any admixture of the vitriolic or marine acids, so as not to require the purification necessary for the common sorts : it is generally too strong for the common purposes of aqua fortis, and is therefore to be diluted with a proper quantity of pure water. The calx of copper may be revived, without much loss, by melting it, in a suitable furnace, in contact with the burning charcoal.

### III. *Purification of gold from silver and base metals by cementation.*

THOUGH the nitrous acid in its liquid state does not extract silver from gold, unless the quantity of silver greatly exceeds the gold ; yet in cementation, where the acid, resolved into fumes, is applied to the metal at the same time strongly heated, it attacks and corrodes a part of the silver though its proportion be very minute.

For this purpose, nitre in substance is mixed with equal its weight of common green vitriol calcined, or dried as for the making of aqua fortis, and with twice its weight of powdered bricks ; the one to extricate its acid when sufficiently heated, and the other to prevent the mixture from growing fluid in the fire. The metal is flatted into thin plates, which are surrounded and interlaid with this powder, in a crucible, or in an earthen vessel made on purpose for this use called a cementing pot : the vessel is closely covered, and the juncture secured with a mixture of soft clay and sand, or other proper clayey compositions ; and being placed in any convenient furnace, a moderate heat is kept up for twelve or sixteen hours. The silver, and most of the base metals along with it, are corroded by the nitrous vapour into a saline concrete, which partly adheres in the pores of the gold,  
and

and is partly dispersed through the mixture. From the gold, the corroded silver may be boiled out with water, and afterwards recovered from the liquor in the same manner as from its solution in aqua fortis: from the mixture, it is much more difficultly extracted, by boiling the matter in melted lead, and afterwards working off the lead, into which the silver has thus transferred itself, upon a cupel or test. The quantity of silver however, which cementation is employed for separating from gold, is commonly so small as to be entirely disregarded.

The acid of sea salt, applied in the same manner, corrodes all the metallic bodies except gold and platina. Hence either sea salt or nitre may be used in this process indifferently; but they must never be taken together, as some have directed them to be, for the two acids in conjunction would dissolve the gold itself. The mixture of sea salt with the calcined vitriol and brickdust has been commonly called the regal cement, from gold, before the discovery of platina, having been the only known metallic body that was capable of resisting it.

The gold plates cannot be wholly freed from their alloy by one operation either with the nitrous or marine cements, the vapours penetrating but a very little way into their substance. Hence for the effectual purification of gold by this method, the metal is to be remelted, flatted into plates, and again exposed to the fumes. The process indeed appears upon the whole to be incommodious, whether considered as a method of purifying gold or of ascertaining its purity; and accordingly, though once in much esteem, it is now rarely practised. Its principal use is for extracting silver or base metals from the surface of gold, and thus giving superficial purity and high colour to alloyed or pale gold.

IV. *Refining of gold from silver and base metals by antimony.*

ANTIMONY consists of a metallic substance united with sulphur. Sulphur has less affinity to the antimonial metal than to silver, copper, or the other metals commonly mixed with gold : and accordingly when antimony and alloyed gold are melted together, the sulphur of the antimony unites with and scorifies the alloy of the gold, while the gold falls to the bottom blended with the metal of the antimony, which last may be afterwards dissipated from it by fire.

One of the greatest difficulties in this process regards the crucibles, which are very liable to crack, and to be corroded by the sulphureous matter. Scheffer relates, that the crucibles he has found to be most durable are those which had been steeped several days in linseed oil ; then cleared from the oil, so as to remain only of such a degree of moistness, that some borax in fine powder may adhere and be spread all over the inner surface ; and afterwards set by to dry slowly : in a crucible thus prepared he says he can perform two or three hundred fusions. It is nevertheless advisable, in a case where the vessel is so apt to fail, to take precautions for preserving its contents in case of such an accident ; as inserting it into another crucible, or placing a basin underneath.

The gold being melted in the crucible, about twice its weight of powdered antimony is thrown upon it, in different parcels, one parcel after another is melted ; with care to prevent the falling in of any pieces of charcoal, which would occasion the antimony to swell and froth up, so as to be apt to run over the vessel : as this swelling up cannot be wholly avoided, the crucible ought to be large. If the gold is very impure, or contains above one  
fourth

fourth its weight of alloy, the antimony is previously mixed with about a fourth part of common sulphur ; because if antimony itself was used in sufficient quantity to scorify all the alloy, the quantity of metal afforded by the antimony would be so large as to render its dissipation from the gold extremely tedious. As soon as the mixture sparkles upon the surface, and appears perfectly fluid, it is poured into a conical brass or iron mould, greased, and equably heated all over till it smokes ; and the support, which the mould stands on, is gently struck or joggled so as to produce a tremulous motion of the fluid matter, by which the settling of the gold is promoted. When the matter is fixed or grown solid, it is easily got out, by inverting the mould and striking a few blows on it with a hammer : the metallic mass, which had subsided into the lower part of the cone, if it does not separate, in coming out, from the sulphureous scoria, is beaten off by a slight blow.

This metallic mass consists of the gold, mixed, instead of its former alloy, with the metal of the antimony. But as part of its alloy may have still escaped the action of the sulphur ; if the gold is required to be of a high purity, it must be melted in the same manner with the same quantity of fresh antimony, and the process repeated a third or even a fourth time. The gold does not receive much addition from the antimony in these last fusions ; the antimonial metal uniting with the gold only in proportion as the sulphur of the antimony is absorbed from its proper metal by the alloy of the gold.

In order to separate the antimonial metal from the gold, the mixt is put into a strong crucible, which being placed in a proper furnace, a fire is kept up, just sufficient to make the matter flow thin with a clear surface. A blast of air being directed upon the mixt, by means of a bent  
copper

copper pipe applied to the nose of a pair of double hand-bellows, the antimonial matter gradually exhales in copious white fumes, which cease on discontinuing the blast, and reappear upon renewing it. The fire must from time to time be increased; for the mass being cooled by the air impelled upon it, a hard skin forms on the surface, and in this state the evaporation does not succeed. When fresh fuel is to be supplied, the crucible should be covered, that no pieces of the charcoal may fall in; and as soon as the metal has come again into sufficient fusion, the blast on its surface is to be repeated, till no more fumes can be made to rise from it, and the gold remains of a clear bright green colour without the least cloudiness.

If the process is continued, as it ought to be, to this point, there will be no occasion for remelting the gold with nitre and borax, as the writers on these subjects generally direct. Where a little of the antimonial matter left in the gold, discoverable by its paleness and brittleness, renders this last operation necessary, the nitre and borax should be added by a little at a time, the matter being extremely apt to swell up and run over the vessel: it is the more disposed to swell up as the antimonial remains are the more considerable.

This process has been commonly supposed to afford the highest purification of gold; and hence antimony has been distinguished by the title of *balneum solius solis*, or the bath which gold alone can support, and by which it is washed from all its impurities. But besides that platina cannot thus be separated from it; if gold containing silver be highly refined by antimony, it will still, on being dissolved in aqua regia, discover a little of the silver, which had been defended by the gold from the action of the antimony. It may be observed in general, that gold cannot be so effectually purified by substances which operate



rate upon the alloy and not upon the gold, as by those which act on the gold itself and not on the alloy.

A small portion of the gold is commonly retained in the sulphureous scoriæ, along with the silver or other metals with which it had been debased. The scoriæ of the last fusions, in which the sulphur and metal of the antimony have suffered little separation, are therefore to be reserved for the same purposes again. From those of the first, both the gold and silver may be recovered, by keeping them in fusion in a crucible, and blowing off the antimonial matter, in the manner above directed for dissipating it from gold.

*V. Purification of gold from platina, silver and base metals by aqua regia.*

AQUA REGIA, in dissolving gold, leaves behind what silver the gold had been mixed with; and certain bodies, added to the solution, separate the gold from it, without being able to separate any metal besides; so that on this principle gold may be brought with ease to its ultimate purity.

The gold, flattened into thin plates or reduced into grains, is to be put into about thrice its weight of moderately strong aqua fortis, and the vessel being set in a gentle heat, a little sea salt is to be added: the dissolution will immediately begin, with a considerable effervescence, and when the action ceases, the addition of a little more sea salt will renew it: the injection of sea salt is to be continued, by a little at a time, till the whole of the gold appears to be dissolved; the quantity of salt requisite is generally about a third of the aqua fortis. The clear part of the solution is to be poured off, and the remainder passed through a double filter of paper: the undissolved  
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matter

matter is to be washed two or three times with water in the filter, and this liquor poured to the rest.

For recovering the gold from the solution, Cramer directs two methods, distilling off the menstruum, and precipitating the gold by mercury. But in either of these ways we cannot be certain of having the gold pure. For though it has been previously cupelled with lead, yet, if it contained any platina, it will retain the whole of the platina after the cupellation, and in some circumstances, as we have already seen, it will retain also a little copper: both the platina and copper will dissolve with it in aqua regia; mercury will precipitate the platina along with the gold; and the abstraction of the menstruum will leave with it both the platina and copper.

The purity of the gold is secured by precipitation with common green vitriol. The vitriol is to be dissolved in cold water, the solution passed through a filter, and added in large quantity to the solution of gold: the quantity of vitriol, before its dissolution, should be ten or twelve times greater than that of the gold. As the precipitate falls slowly, the mixture is to be set by for twenty four hours or more: the liquor, then become clear, though of a deep colour, is to be poured off; the brownish powder at the bottom, boiled in a little aqua fortis, then washed with water, and melted with the addition of a little nitre.

Gold, thus purified, appears to be perfectly fine; a point not obtainable by any other known means that can be practised in the way of business. Nor does the process seem to be so expensive as the imperfect one by aqua fortis; for there, three parts or more of silver being added to one of gold, at least six parts of aqua fortis are required for dissolving the silver; whereas the gold, in the above process, may be dissolved by half that quantity of the menstruum: great part of the acid may like-  
wise

be recovered by distillation from the liquor which remains after the gold has fallen.

Kunckel is the first who has taken notice of this precipitation by vitriol: but having used a vitriol which partook of copper as well as iron, he seems to have thought that the effect depended on the copper, and recommends the bluest and most venereal of the common sorts of vitriol as the best: accordingly most of those, who have mentioned this process, direct blue vitriol or vitriol of copper. I have not found that blue vitriol produces the least precipitation in solution of gold; so that, by this misapprehension in regard to the nature of the precipitant, Kunckel's discovery was rendered useless, till Brandt happily observed, that green vitriol produces the effect which had been ascribed to the blue.

VI. *Extraction of a small portion of gold from a large quantity of silver.*

THE most advantageous method of separating a small proportion of gold from a large one of silver appears to be by means of sulphur, which unites with and scorifies the silver, without affecting the gold. But as sulphurated silver does not flow thin enough to suffer the small particles of gold, diffused through it, to reunite and settle to the bottom, some addition is necessary for collecting and carrying them down.

In order to the commixture with the sulphur, fifty or sixty pounds of the mixt metal, or as much as a large crucible will receive, are melted at once, and reduced into grains by lading out the fluid matter, with a small crucible made red hot, and pouring it into cold water stirred with a rapid circular motion. From an eighth to a fifth of the granulated metal, according as it is richer or poorer in gold, is reserved; and the rest well mingled with an

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eighth of powdered sulphur ; which easily adheres to the moist grains. The grains, enveloped with the sulphur, are put again into the crucible, and the fire kept gentle for some time, that the silver, before it melts, may be thoroughly penetrated by the sulphur : if the fire was hastily urged, great part of the sulphur would be dissipated, without acting upon the metal.

If to sulphurated silver in fusion, pure silver be added, the latter falls to the bottom, and forms there a distinct fluid, not miscible with the other any more than water is with oil. The particles of gold, having no affinity to the sulphurated silver, join themselves to the pure silver, wherever they come in contact with it, and are thus transferred from the former into the latter, more or less perfectly according as the pure silver was more or less thoroughly diffused through the mixt. It is for this use that a part of the granulated matter was reserved.

The sulphurated mass being brought into perfect fusion, and kept melted for near an hour, in a close covered crucible, one third of the reserved grains is thrown in, and as soon as this is melted, the whole is well stirred, that the fresh silver may be distributed through the mixt to collect the gold from it : the stirring is performed with a wooden rod : an iron one would be corroded by the sulphur, so as to deprive the mixt of its due quantity of the sulphur, and likewise render the subsequent purification of the silver more troublesome. The fusion being continued an hour longer, another third of the unsulphurated grains is added, and an hour after this, the remainder ; after which the fusion is further continued for some time, the matter being stirred at least every half hour from the beginning to the end, and the crucible kept closely covered in the intervals.

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The sulphurated silver appears in fusion of a dark brownish colour. After it has been kept melted for a certain time, a part of the sulphur having escaped from the top, the surface becomes white, and some bright drops of silver, about the size of peas, are perceived on it. When this happens, which is commonly in about three hours after the last addition of the reserved grains, sooner or later according as the crucible has been less or more closely covered, and the matter more or less stirred, the fire must be immediately discontinued; for otherwise more and more of the silver, thus losing its sulphur, would subside, and mingle with the part at the bottom in which the gold is collected. The whole is poured out into an iron mortar greased and duly heated; or if the quantity is too large to be safely lifted at once, a part is first laded out from the top with a small crucible, and the rest poured into the mortar. The gold, diffused at first through the whole mass, is now found collected into a part of it at the bottom, amounting only to about as much as was reserved un sulphurated. This part may be separated from the sulphurated silver above it by a chisel and hammer; or more perfectly, the surface of the lower mass being generally rugged and unequal, by placing the whole mass, with its bottom upwards, in a crucible: the sulphurated part quickly melts, leaving unmelted that which contains the gold, which may thus be completely separated from the other. The sulphurated silver is assayed, by keeping a portion of it in fusion in an open crucible, till the sulphur is dissipated, and then dissolving it in aqua fortis: if it should still be found to contain any gold, it is melted again, as much more un sulphurated silver added, as was employed in each of the former injections, and the fusion continued about an hour and a half.

The gold, thus collected into a part of the silver, may be further concentrated into a smaller part, by granulating the mass, and repeating the whole process. The operation may be again and again repeated, till so much of the silver is separated, that the remainder may be parted by aqua fortis without too much expence.

The foregoing process, according to Schlutter, is practised at Rammelsberg in the lower Hartz. The prevailing metal in the ore of Rammelsberg is lead: the quantity of lead is at most forty pounds on a quintal or hundred pounds of the ore: the lead, worked off on a test or concave hearth, yields about a hundred and ten grains of silver, and the silver contains only a three hundred and eighty fourth part of gold: yet this little quantity of gold, amounting scarcely to a third of a grain in a hundred pounds of the ore, is thus collected with profit. The author above mentioned confines this method of separation to such silver as is poor in gold, and reckons parting with aqua fortis more advantageous where the gold amounts to above a sixty fourth of the silver: he advises also not to attempt concentrating the gold too far, as a portion of it will always be taken up again by the silver. Mr. Scheffer however relates, that he has by this method brought the gold almost to perfect fineness, and that he has likewise collected all the gold which the silver contained; the silver of the last operations, which had taken up a portion of the gold, being reserved to be worked over again with a fresh quantity of gold-holding silver. The sulphurated silver is purified by continuing it in fusion for some time, with a large surface exposed to the air; the sulphur gradually exhales, and leaves the silver entire: the particular method of managing this operation will be given hereafter in the history of silver.

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Mr. Eller, in the memoirs of the Berlin academy for the year 1747, describes a process somewhat different from the foregoing; which has been kept a secret in a few hands; and from which, he says, Saxony has for several years reaped considerable profits, by the separation of gold from gilt laces.

The metal being granulated, a part of the grains is mixed with half their weight of litharge and an eighth of sandiver: this is called the precipitating mixture. The rest are mingled as above with powdered sulphur, and exposed to a gradual fire till they are brought into fusion, which is known to be perfect, when the surface, on lifting up the cover of the crucible, appears coloured, chiefly with red and yellow, and the colours come and go, as if something attracted them. To every thirty-two ounces of the sulphurated metal, one ounce of the precipitating mixture is added, at three different times, at intervals of at least five or six minutes; after which, the crucible is covered again, and the fusion continued seven minutes. Part of the matter being now laded out, the rest is poured off, till a metallic mass shews itself at the bottom: this is easily distinguishable, by its bright fiery aspect, from the sulphurated mixt, which is of a leaden brown colour.

The silver poured off, still containing a little gold, is treated in the same manner a second and a third time, except that in the third another precipitant must be used; for that employed in the two first, being partly composed of silver not freed from its gold, would add to the sulphurated silver, now almost entirely purified from gold, more gold. The precipitant is now a mixture of equal parts of pure copper and lead, melted together and reduced into grains. . If aqua fortis should still discover a little gold in the silver, which never happens unless the silver contained  
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a large quantity at first, the precipitation is repeated a fourth time.

The several metallic masses, thus precipitated, are to be granulated, sulphurated, and further concentrated by the same precipitants as before; about an eighth part of lead being added, before the granulation, which is said to render the mixt more fusible, and promote the separation of the gold. It is probable that bismuth would answer better in this intention, as it forms both with the metals and with the sulphur a much more fusible compound than lead does, and possesses also all the other properties of lead that appear to be here required.

The matter which now subsides is again granulated, mixed with a sixteenth of sulphur, kept in fusion about half an hour, the scoria poured off, and the remaining mass treated in the same manner, without any precipitant, a second or a third time. The gold being now so far concentrated as to exhibit a yellow colour, the mass is melted with a sixteenth of copper, then granulated, the grains mixed with a sixteenth of sulphur, cemented for some time in a heat below ignition, after which, the fire being raised, the matter is kept in fusion about fifteen minutes, and then poured out into a greased and heated mould: the gold is found at the bottom, commonly of a brass colour, and about the fineness of eighteen carats: if too pale, the last operation is repeated with half the quantity of copper; after which the gold is further refined by antimony as already described.

#### VII. *Extraction of gold from copper.*

FOR separating gold from large proportions of copper, as from the gilt clippings left by the button-maker, some of our refiners have recourse to cupellation or testing with lead. But the long continuance of fire and great quantity



of lead necessary for scorifying so large a proportion of copper, and the difficult revival of the copper from the scoria, render the process too expensive for the produce of gold.

Some have melted the gold-holding copper with about thrice its quantity of lead, and cast the mixture into cakes; which being ranged in the higher part of a sloping canal, and moderately heated, it was expected that the lead, melting out and running down from the copper, would carry the gold with it. But though this process succeeds for the separation of silver from copper, it is otherwise in regard to gold: if the copper contains both gold and silver, only the silver melts out with the lead, the gold remaining behind in the unmelted mass of copper.

Alonso Barba gives a method which may in several cases be practicable to advantage. The copper is calcined with sulphur, till it becomes pulverable, and the powder ground with quicksilver in the same manner as earthy or stony bodies containing gold: the mercury imbibes the gold, without acting upon the calcined copper, which may now be washed off with water.

Many processes have been given for separating gold from copper by precipitating powders, which are composed of very discordant materials, as antimony, lead, sulphur, crocus of iron, mercury-sublimate, arsenic, vitriol, verdgris, alum, nitre, sal ammoniac, wood ashes, quicklime. Though these processes, a number of which is collected by Swedenborg in the third volume of his *regnum subterraneum*, are apparently so injudicious, that an artist can have no inducement to make trial of them, yet they are not altogether without foundation: lead and sulphur, as Barba intimates, and as an experiment of Mr. Scheffer's has shewn more satisfactorily, are the useful ingredients; and by means of these ingredients, gold may be extracted  
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from copper more advantageously than by any other known method.

The way of procedure is as follows. Some litharge, or any other calx of lead, is melted with about an equal quantity of sulphur, with which it unites into a sparkling mass, of a semimetallic aspect, and nearly of the same quality with the common lead ores. The copper being brought into fusion, this mixture is thrown upon it, by a little at a time, till the quantity of lead becomes nearly equal to that of the copper: the copper absorbs the sulphur from the lead, and the lead, being in a state of calx, remains uniformly blended with the sulphurated copper. A little powdered charcoal is then thrown in, and the whole well stirred with an iron rod: the lead is immediately revived into its metallic form, and sinking to the bottom carries the gold with it; neither lead nor gold having any affinity to sulphurated copper. The effect is the same when the copper is first sulphurated, and the litharge or calx of lead added to this mixture; and probably gold might be separated in the same manner from sulphurated iron.

#### VIII. *Separation of gold from gilt works.*

THE solubility of gold and the indissolubility of silver in aqua regia affords a principle on which gold may be separated from the surface of silver; and on this foundation different processes have been contrived, of which the two following appear to be the best. Some powdered sal ammoniac, moistened with aqua fortis into the consistence of a paste, is spread upon the gilt silver, and the piece heated, till the matter smokes and becomes nearly dry: being then thrown into water, it is rubbed

together, by which the gold easily comes off. The other way is, by putting the gilt silver into common aqua regia, kept so hot as nearly to boil, and turning the metal frequently till it becomes all over black : it is then to be washed with a little water, and rubbed with the scratch brush, to get off what gold the aqua regia may have left. This last method appears preferable to the other ; as the same aqua regia may be made to serve repeatedly till it becomes saturated with the gold, after which the gold may be recovered pure by precipitation with solution of vitriol, as directed in the fifth article of this section.

For separating gold from gilt copper, some direct a solution of borax to be applied on the gilt parts, but no where else, with a pencil, and a little powdered sulphur to be sprinkled on the places thus moistened ; the principal use of the solution of borax seems to be to make the sulphur adhere ; the piece being then made red hot, and quenched in water, the gold is said to be so far loosened, as to be wiped off with a brush. Others mix the sulphur with nitre and tartar, and form the mixture with vinegar into a paste, whicy is spread upon the gilt parts.

Schlutter recommends mechanical means, as being generally the least expensive, for separating gold from the surface both of silver and copper. If the gilt vessel is round, the gold is conveniently got off by turning it in a lathe and applying a proper tool, a skin being placed underneath for receiving the shavings : he says it is easy to collect into two ounces of shavings all the gold of a gilt vessel weighing thrice as many pounds. Where the figure of the piece does not admit of this method, it is to be properly fixed, and scrapers applied, of different kinds according to its size and figure, some large and furnished with two handles, one at each end, others small and narrow for penetrating into depressed parts. If the

gold cannot be got off by either of these ways, the file must be had recourse to, which takes off more of the metal underneath than the turning tool or the scraper, particularly than the former. The gold scrapings or filings may be purified from the silver or copper they contain by the methods described in the preceding part of this section.

The editors of the *encyclopedie* give a method of recovering the gold from wood that has been gilt on a water size: this account is extracted from a memoir on the same subject presented to the academy of sciences by M. de Montamy. The gilt wood is steeped for a quarter of an hour, in a quantity of water, sufficient to cover it, made very hot: the size being thus softened, the wood is taken out, and scrubbed, piece by piece, in a little warm water, with short stiff bristle brushes of different sizes, some small for penetrating into the carvings, and others large for the greater dispatch in flat pieces. The whole mixture of water, size, gold, &c. is to be boiled to dryness, the dry matter made red hot in a crucible to burn off the size, and the remainder ground with mercury, either in a mortar, or, where the quantity is large, in a mill, as described hereafter, in the eleventh section: some clean sand is directed to be added, which is said to occasion the gold to be easier laid hold of by the mercury.

## S E C T. X.

*Of tinging glass and enamel by preparations of gold.*

THE tinging of glass and enamels by preparations of gold appears to have been first attempted about the beginning of the last century, Libavius, whose works compose a valuable body of the chemical knowledge of his own time, conjectures, in one of his tracts entitled *Alchymia*, printed in 1606, that the colour of the ruby proceeds

proceeds from gold, and that gold dissolved and brought to redness might be made to communicate a like colour to factitious gems or glass. Neri, in his art of glass dated 1611, gives a process on this principle, which he says was found to succeed: he directs the gold to be dissolved in aqua regia, the menstruum to be evaporated or drawn off by distillation, more aqua regia added, and the abstraction repeated five or six times: the remaining matter is to be calcined till it becomes purple, and then mixed with a proper quantity of the finest white or crystal glass. But though this process may be supposed to have sometimes proved successful, it doubtless very often miscarried; inasmuch that the introduction of this desirable colour into glass was very little known for many years after.

Glauber, in the second part of his philosophical furnaces published in 1648, gives another method of producing a red colour by gold in a matter which is of the vitreous kind, though not perfect glass. When powdered flint or sand is well ground with four times its weight of fixt alkaline salt, the mixture melts in a moderately strong fire, and when cold looks like glass, but on account of its over-proportion of alkaline salt it runs into a liquid state on being exposed to the air: on adding this liquor to solution of gold in aqua regia, the acid, which held the gold dissolved, unites with the alkali which held the flint dissolved, and the gold and flint precipitate together, in form of a yellow powder, which by calcination becomes purple: this powder being mixed with three or four times its weight of the alkaline solution of flint, the mixture dried, and kept melted in a strong fire for an hour, a mass is obtained, of a transparent ruby colour, and of a vitreous appearance, though still soluble in water or by the moisture of the air, on account of the redundancy of salt.

Boyle, in his treatise on the porosity of bodies, and in the appendix to his sceptical chymist published in 1680, mentions an experiment, in which a like colour was introduced into glass without fusion. A mixture of gold and mercury having been kept in digestion for some months, the fire was at last immoderately increased, inso-much that the glass burst with a violent explosion: the lower part of the glass was found tinged throughout of a transparent red colour, which seemed, he says, to emulate that of a not common ruby.

About the same time Cassius discovered the precipitation of gold by tin, and that glass might be tinged of a ruby colour by melting it with this precipitate. I can give no further account of his experiments, having never had the good fortune to meet with his treatise.

The process was soon after brought to perfection by Kunckel, who says he prepared the ruby glass in large quantity, and sold it for about forty shillings an ounce; and that he made a chalice of it for the elector of Cologne, weighing no less than twenty four pounds, a full inch thick, and of an uniform fine colour throughout. He has no where communicated the process he followed, but some useful observations relating to it are dispersed through his writings: he says, that one part of the precipitate by tin is sufficient to give a ruby colour to twelve hundred and eighty parts of glass, and a sensible redness to upwards of nineteen hundred parts: that the success is by no means constant, and that after long practice, he still frequently failed: that oftentimes the glass comes out of the fire colourless as crystal, and receives its ruby colour on being afterwards exposed to a smoky flame, inso-much that he imagines the discovery of the ruby glass did not arise from simply melting the gold precipitate with glass, but from the subsequent softening

ening and working of the glaſs in the flame of a lamp, in the uſe of which Caſſius was very converſant: that the addition of nitre and ſal ammoniac calls forth the colour, and that the colour produced by ſal ammoniac is more beautiful than that by nitre, but \*quickly diſappears on a continuance of the fire.

Orſchal, in a treatiſe entitled *ſol ſine veſte*, gives a proceſs, by which he ſays he obtained a very fine ruby. He directs the purple precipitate, made by tin, to be ground with ſix times its quantity of Venice glaſs in very fine powder, and this compound to be exquisitely mingled with the fritt or vitreous compoſition to be tinged: his fritt conſiſts of equal parts of borax, nitre, and fixt alkaline ſalt, and four times as much calcined flint as of each of the ſalts; but in what proportion the gold precipitate is to be mixed with the fritt, and in what manner the fuſion is to be performed, he does not mention. He reports that he had found the muddy matter, obtained in poliſhing gold by a pumice ſtone, to impart likewiſe a ruby colour to glaſs.

Grummet, who had been operator to Kunckel in making the red glaſs, publiſhed a tract in oppoſition both to him and Orſchal, under the title of *ſol non ſine veſte*, in which he obſerves, that the furnace ought to be ſo conſtructed, that the operator may have full liberty of examining the glaſs in the fire, and of removing it as ſoon as it appears to have acquired the proper colour: he ſays the enamellers obtain a ruby colour, by melting, with a large proportion of Venice glaſs, the browniſh powder precipitated from ſolution of gold in aqua regia by fixt alkaline ſalts. But he imagines that the gold is nowiſe concerned in the production of the colour. Venice glaſs, and moſt of the finer colourleſs kinds of glaſs, have an addition of manganese, without which it would be very difficult

cult to render them perfectly void of colour : the manganese communicates at first a purplish hue, which on continuing the fire disappears, and at the same time suppresses or discharges any other tinge that the glass may be impregnated with : the addition of a little nitre revives the purplish colour of the manganese, and Grummet is of opinion that the colour with which glass becomes tinged, by the admixture of preparations of gold, is no other than that of the manganese extricated by the nitrous salt which the gold has retained in its precipitation. He affirms that the same purplish red colour will be obtained on melting Venice glass with an eighth part of nitre, without any gold ; that in a hundred repetitions of this experiment, it scarcely fails once ; and that neither nitre nor the gold-precipitate were found to give any thing of the admired colour to those kinds of glass which have no manganese in their composition.

The colours which manganese imparts to glass, it belongs not to this place to examine : but that precipitates of gold will communicate, in certain circumstances, a purplish red colour, I have several times experienced ; having myself tinged of this colour fritts composed of calcined flint, nitre and borax, without the addition of any manganese or of glasses containing it. Though gold, dissolved in common aqua regia, exhibits its own yellow colour ; yet, when the menstruum is separated by fire to a certain point, or when the gold is precipitated by tin, or when it is precipitated by alkaline salts and afterwards moderately heated, or when the gold is barely divided by mechanical means into subtile powder, and exposed for some time, in mixture with earthy bodies, to a slight heat, it assumes, in different circumstances, a violet colour, a purple, or a red verging to purple : in a strong fire, these colours vanish, and the gold melts into a mass of its original



ginal appearance. All these colours I have introduced into glass by preparations of gold; and I have found them to be nearly as perishable in the fire when the coloured gold powder was thus diffused through the glass, as when exposed to the fire by itself: when the fire was raised to any great degree, and the glass made to flow thin, there was generally a button of revived gold collected at the bottom.

A solution of gold in aqua regia being inspissated to dryness in the bottom of a Florence flask, and the heat further increased till the gold resumed its proper colour, the lower part of the glass was by this simple process tinged purplish: pieces of it being exposed to the flame of a lamp, they became in some parts violet coloured, in some of a bright purple, and in others purplish red; and the parts which in one position looked violet or purplish, in another appeared red.

A colour nearly of the same kind is impressed on glass by gold leaf in some electrical experiments; a fact which we are obliged to Mr. Franklin for the first knowledge of. A narrow strip of gold leaf being placed between two slips of glass, with both the ends hanging out a little, and the glass well tied round with silk thread, a strong electrical explosion is made to pass through the gold leaf. On examining the glass, the gold leaf, he observes, will be found missing in several places, and instead of it a reddish stain on both the glasses, exactly similar on both in the minutest stroke, though sometimes spread a little wider than the breadth of the leaf: the stain appears to have penetrated into the substance of the glass, so as to be protected by it from the action of aqua regia. I have had this experiment several times repeated with plate glass, and found it tinged, as above described, in some parts violet, in some purplish, and in some reddish; the colours could not be scraped off,  
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and resisted aqua regia and spirit of salt. If the electric explosion is made very strong, the glass commonly flies in pieces, with such force, that it is necessary for the operator to have his face screened from them.

The preparation of gold which has been principally recommended for tinging glass is Cassius's precipitate by solution of tin. To obtain this precipitate of the due colour, a good deal of care is necessary both in dissolving the tin, and in diluting the solutions. A mixture of two parts of aqua fortis and one of spirit of salt is supposed to be the best menstruum for the tin: into this mixture some fine block tin, granulated, is to be let fall, grain by grain, waiting till one grain is dissolved before another is dropt in, that the dissolution may go on slowly, without any heat or discharge of fumes. The gold is dissolved in common aqua regia; and a few drops of this solution being mixed with some ounces of pure water, as many drops of the solution of tin are added. If the mixture changes immediately to a clear bright purplish red colour, the due degree of dilution has been hit; if the colour appears dull, a greater quantity of water must be added for the rest of the solutions. After the mixture has deposited its red matter, and become clear, a little more of the tin solution is to be dropt in, for discovering, and precipitating, any gold that may still remain in it: the liquor being then poured off, the precipitate is washed and dried.

Kunckel mentions another purple gold-powder, made nearly like that of Neri already mentioned, by inspissating solution of gold to dryness, abstracting from it fresh aqua regia three or four times till the matter looks almost like oil, then precipitating with strong alkaline ley, and washing the precipitate with water. By dissolving this powder

in spirit of salt, and precipitating again, it becomes, he says, extremely fair, and in this state he directs it to be mixed with a due proportion of Venice glass.

Hellot describes a preparation which in mixture with Venice glass was found to give a beautiful purple enamel. Equal parts of solution of gold, and of solution of zinc in aqua regia, are mixed together; and a volatile spirit, prepared from sal ammoniac by quicklime, added to the mixture in sufficient quantity to precipitate the two metals. The precipitate is to be gradually heated, till it acquires a violet colour: it does not fulminate, making only a slight dull decrepitation without any of its particles flying about.

Though a purple, or a red colour approaching to that of the ruby, may by the foregoing means be baked upon glass or enamels, and introduced into the mass by fusion, the way of equally diffusing such a colour through a quantity of fluid glass is still a secret.

I was once, many years ago, fortunate enough to succeed, at a glass-house, in a small pot of glass, of which a salver was blown of a fine ruby red: the tinging matter was the precipitate of gold by tin; the particulars of the process cannot now be recollected. I have since tried the remainder of the same preparation, with common flint glass, with green glass, with various fritts composed of flint, borax, pure fixt alkaline salt, nitre, sal ammoniac. When flint was used, it was several times made red hot, and quenched in water, to render it more easily pulverable: both the flint and glasses were powdered in an iron mortar, and the powders well washed with diluted oil of vitriol, to extract such particles of iron as they might have worn off in the trituration; the gold precipitate was ground with the other ingredients, in agate or glass mortars; its proportion was varied from an eighth part to

an eight hundredth of the vitreous materials ; and the fire was continued, in a wind furnace, from six to thirty hours. All the glasses came out considerably coloured ; some of a deep dusky yellow ; some of a fine pale transparent yellow ; some of a brown colour, greatly resembling that which the glass mentioned in the following page acquired under a muffle : some appeared yellowish or brownish when looked down upon, and of a purple-violet or reddish purple when held between the eye and the light : some had specks and veins of a fine red ; no one was either red or purple throughout. Several of these glasses were melted again and again, by themselves, and with the addition of more vitreous matter : some were worked in the flame of a lamp : some were laid in a mixture of powdered charcoal and foot, and made red hot in a close crucible ; and others being laid in the same manner, the fire was increased till they melted. The colours were by these means altered, but did not become uniform, or more approaching to the ruby colour than before : some pieces, which had at first very considerable specks of a ruby lustre, lost them on a repetition of the fusion.

At the same time that these experiments were tried, the same kinds of vitreous compositions, mixed with different metallic preparations, were exposed to the fire in different parts of the same furnace, and were all found to receive beautiful and uniform colours, of which an account will be given in their places. To what cause the miscarriage of those with gold was owing, whether the success, in regard to this metal, is influenced by the quantity of the matter, by the unsteadiness of the heat in a small furnace, by the fusibility of the vitreous composition, by the metallic matter being ground with the ingredients before their exposure to the fire or added to them

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in fusion, by the continuance of the fire, by the fluid matter being kept unmoved or stirred with an iron rod, by the crucible being covered or open, or other like circumstances, or whether the admixture of a little manganese, though gold will certainly give a ruby colour without it, does not contribute to secure the success, I have not yet discovered. The proportion of the gold precipitate to the vitreous matter is perhaps of principal importance. Solution of gold, as we have seen already, produces no redness with tin unless diluted with a very large quantity of water, in which circumstance the whole mixture acquires that beautiful colour which we here want to transfer from the watery fluid into fluid glass: it should seem therefore that the quantity of gold precipitate, for communicating the admired colour to a certain volume of glass, ought to be the same with that, which communicated a like colour to an equal volume of water in the precipitation: a quantity extremely minute, and much less than that employed in any of my experiments.

I have lately been favoured with some pieces of glass, in greatest part colourless, with one or two large red spots, several small streaks of violet, and some of a light brownish yellow. The person from whom I received them informs me that he had "found that in a heat not very strong, under a muffle, the glass becomes of an opaque brown, and, if then polished, appears variegated like a fine pebble." I exposed a colourless piece to the flame of a lamp, impelled by a blow pipe, and on working it about, sometimes in the smoke and sometimes in the flame, found it change to a true ruby red, perfectly transparent, and free from veins of any other colour. Another piece, kept for two hours under a close muffle, in such a heat as made it just soft enough to bend and receive an impression, became on the surface

green, brown and pale yellow in different parts, greatly resembling the coat of some pebbles : in this state, looked through against the sun, it appeared of a beautiful ruby colour, and on breaking it, the internal part was found throughout of an uniform dark red when looked down upon, and of the ruby red when placed between the eye and the light. A large piece being continued under the muffle for four hours, its figure was found scarcely altered, the coat was much thicker and beautifully veined with various colours, which were all lost in a glorious red when the piece was viewed between the light.

All I have been able to learn in regard to the preparation of this glass is, that the quantity made at once is about six hundred weight ; that the tinging matter is mixed with the vitreous materials before they are put into the melting pot, the mixture being brought to the glass-house in tubs ; that the matter is not stirred in fusion ; and that it is kept no longer in the fire than is necessary for perfecting the glass, which, as soon as fine, is cast into a kind of bricks. Some imagine that this glass has no mixture of calx of lead, of which a large proportion is used in the composition of the common flint glass, and that the principal vitrefying ingredient is nitre : others judge it to be composed of the same materials as the common sort ; its weight seeming to be a proof of its containing lead, for it is found to be nearly of the same specific gravity with flint glass, which is greater than that of the glasses made without lead in the proportion of above six to five. This point I have determined in a more satisfactory manner : four hundred grains of the glass, made red hot and quenched in water, were reduced into powder, and mingled with about twice as much black flux and a little alkaline salt : the mixture being melted in a crucible, and the vessel suffered to cool, a  
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lump of metal was found at the bottom, weighing ninety grains. The metal appeared to be somewhat stiffer than pure lead, and experiments convinced me that it contained some tin and a little gold.

## S E C T. XI.

### *The mineral history of gold.*

**G**OLD is found in its perfect metallic state; sometimes in masses of considerable magnitude; more frequently in dust or minute grains, intermingled among earths and sands; or in little drops and veins, bedded in different coloured stones, which strike fire with steel, and are not soluble in aqua fortis. It is never debased into a true ore, as other metals generally are, by the coalition of arsenical or sulphureous bodies; though it is often very intimately combined in the composition of sands and stones, and blended, in small proportion, with the ores of other metals. It is scarcely ever free from some admixture of other metals, particularly of silver: Cramer observes, that such as is found loose in earths and sands generally contains more silver than what is lodged in a solid matrix. To such an admixture is apparently owing the paleness of some kinds of gold: and probably the Malaccassian gold, said by Flacourt, in his history of Madagascar, to be not only paler but much more fusible than that of Europe, and which has hence been supposed by some to be in its own nature distinct, is no other than a mixture of gold with a certain quantity of silver: it is said to be of considerably less value than the European gold, from which circumstance, omitted by Boyle and others who have quoted Flacourt's account, it may be presumed that it is not regarded, upon the spot, as being pure gold.

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The Brasils, the Spanish West Indies, some parts of the East Indies and the coast of Africa afford the largest quantities of gold. Some parts of Europe also appear to be rich in this metal: the mines of the upper Hungary, which seem to be the most considerable in this quarter of the world, have continued to yield gold for upwards of ten centuries.

Peru, Mexico, Chili, and other provinces of the Spanish West Indies, abound with gold in a variety of forms. It is found both in the sands of rivers, and in mines; intermixed with loose earth, lodged in fissures of rocks, and bedded in hard stones; at the surface of the earth, and at great depths; in dust, in grains like the seeds of apples, called pepitas, and sometimes in masses of an extraordinary size. Reaumur reports that a piece was shewn to the French academy, which was said to weigh fifty-six marcs, or four hundred and forty-eight ounces; and Feuillée says he saw one, in the cabinet of Antonio Portocarero, which weighed upwards of sixty-six marcs or five hundred and twenty-eight ounces. Both these pieces were assayed, and found to be of different fineness in different parts of the mass: the first was in one part twenty-three carats and a half, in another twenty-three, and in another only twenty-two: the second was in one part twenty-two carats, in another twenty-one, and in another but seventeen and a half. It is, however, rare to meet with masses of the weight even of an ounce: the largest in the British museum weighs but fifteen penny-weight. Notwithstanding the extensive dissemination of it through those provinces, yet the quantity of the gold, in proportion to the earthy and stony matter mixed with it, appears to be in general exceeding small. According to Frezier in his voyage to the south sea, and Captain  
Bretagh's



Bretagh's account printed in Harris's collection, the common yield is no more than five or six ounces of gold upon the caxon or fifty hundred pounds of the mineral: the richest mines afford only ten or twelve ounces, and those which are but just rich enough to pay the charges of working of them, yield only two ounces on that quantity. It may be observed in general, that the quantity of gold in minerals is more variable than that of other metals in their ores, and the profits of a gold mine more precarious; this metal not being formed into any regular veins, or uniformly distributed through any particular kind of earth or stone, but scattered as it were here and there through different mineral bodies: when united with other metals in their ores, its proportion is by no means constant, though in this case it is subject to much less variation than when it is barely bedded in earths or stones.

Of the source of the gold of the East Indies and of Africa, we know but little. From Cape-coast on the coast of Guinea we receive yearly between two and three thousand ounces of gold dust, which is supposed to be collected from the sands of rivers; and some European traders are said to have been witnesses of the richness of the sands in certain parts of that coast. In Hook's posthumous papers an account is given of a person having met with great quantities of gold in the sands of one of the rivers, the sand seeming to grow richer and richer as he advanced further up: in some places he says he gained sixty-three grains of gold from five pounds of sand, and he seems afterwards to have met with much more profitable spots. Three or four hundred ounces, as I am informed, are collected yearly from the sands of the Gambia, and cast into bars at James-fort, one of our settlements on that river.

It is said, that the gold dust from Africa, in its purest state, is from twenty-one to upwards of twenty-two carats fine ; but that the natives frequently mix with it filings of brass. This admixture may be distinguished by the hydrostatic balance, the specific gravity of brass not being half so great as that of the gold dust : in this way of examination great care must be taken to make the water penetrate as perfectly as possible into all the interstices so as to come into close contact with every particle. A little aqua fortis also, poured on the mixture, will immediately discover the fraud, receiving, from the copper in the brass, a blue tincture. It has been suspected, that if the gold be naturally alloyed with a little copper, this trial will prove fallacious, and that the natural copper will tinge the menstruum equally with that which is added by art : of this, however, there is no danger, the natural alloy not being in distinct particles, but diffused through each mass or particle of the gold, so as to be covered by the gold, and protected from the action of the menstruum. There are several other means by which this abuse may be discovered : if the dust be spread thin on a piece of white paper, and moistened with any volatile alkaline spirit, as that of hartshorn, of sal ammoniac, or of urine, the spirit will in a few minutes dissolve so much of the copper as to stain the paper blue : stale urine itself has a like effect, in an inferior degree ; and a solution of crude sal ammoniac, applied in the same manner, produces a greenish stain.

There are sundry European rivers which roll particles of gold with their sands, in no great quantity, yet such, that the neighbouring inhabitants, at certain seasons, find their account in collecting them. M. de Reaumur, in an essay in the French memoirs for 1718, drawn up from materials furnished by the intendants of the several provinces

vinces in pursuance of the orders of the duke of Orleans, gives an account of ten rivers or rivulets in the territories of France that have gold mixed with their sands in certain parts of their course: the Rhine, from Brisac down to Strasburg sparingly, from thence to Philipzburg more abundantly, and most of all so between Fort Louis and Germesheim: the Rhone, in the pais de Gex, from the conflux of the Arve, from which it is supposed to receive its gold, to about five leagues lower down: the rivulets of Ferriet and Benagues, which rise from the heights on the left hand of the descent from Varilhere to Palmiers: the Ariege, *aurigera*, about Palmiers, below where it receives the two foregoing rivulets: the Garonne, some leagues from Toulouse, below where it receives the Ariege: the Salat, which rises, as the Ariege, in the Pyreneans: the Ceze and the Gardon, which come from the Cevennes; and the Doux in Franche-Comté. The last of these rivers is the poorest, the gold having hitherto been collected from it rather in the way of curiosity than in a lucrative view: the greatest quantities are obtained from the Rhine, not that this is really the richest, but on account of its sands being the most industriously searched, for some of the others, particularly the Ceze and the Gardon, appear to be at least equal to it in richness. The quantity got from the Rhine, in an extent of near two leagues below Strasburg, is said to amount to no more than four or five ounces in a year: this is the quantity brought to the magistrates of Strasburg, who farm out the right of collecting it on condition of its being sold to them at a price considerably under its value, so that it may be presumed that a part is otherwise disposed of, and that the quantity really obtained is considerably greater.

There are many other rivers reported to yield gold, as the Tagus, the Danube, the Elb, the Oder, the Inn, the

Sala, &c. The Schwartz, in the county of Schwartzburg in upper Saxony, is said to be rich in this metal, and its sands to be worked with great profit: Stahl mentions a piece found in it as broad as a middling bean, though not so thick, and supposes that the Sala receives all its gold from this river; the gold of the Sala being found only below where the Schwartz enters it, and being less plentiful and in smaller grains. It is generally reckoned that the gold particles, in all auriferous rivers, are washed out by the stream from some rich beds, and afterwards rest or settle where the current is languid, or in places where they escape its force: from what particular sources the gold in different rivers proceeds, does not seem to have been examined.

The richest parts of rivers, within the extent in which they roll gold, are those where their course is slow and interrupted, where they widen or change their direction: the most favourable season is when the water has subsided after a flood. The appearance of the sand affords an useful mark for distinguishing the richest spots; the gold being always most plentiful where the sand is reddish or blackish, or of a colour somewhat different from what is seen elsewhere; not that the red or black sands have any natural connexion with the gold, but on account of their being more ponderous than the white, so that the same cause, which determines the particles of gold, determines these also to subside. The black sand abounds with iron, being vigorously attracted by the magnet; the red, viewed in a microscope, appears, as Reaumur observes, a beautiful congeries of coloured crystals, imitating all the gems known to the jeweller, among which those of the ruby and hyacinth tints are the most common, whence the reddish colour of the sand to the naked eye; the particles of gold are of irregular figures,

figures, but constantly flat, smooth, and with the edges rounded off.

Some gold has been discovered in Britain, at different times, though hitherto in little quantity. Instances are mentioned in Houghton's collections, from Camden, Sibbald, and Gerard de Malines, of gold found in Scotland, about the head of the Clyde, in Crawford-moor; and Boyle says he had from some part of Scotland divers large grains of gold, taken up near the surface of the earth, over a lead mine, one of which, clear from spar, weighed two hundred and one grains. Mr. Boyle had also an English tin ore, wherein there lay, in little cells, a number of small leaves or chips of gold: he observes that though the tinmen, unable to separate them to profit, usually melted both metals together, he was assured that one person advantageously employed his children to pick out the gold from the ore skilfully broken. Some earlier writers mention also gold found in the tin ores of Cornwall, and about the beginning of the present century a patent is said to have been obtained "for separating gold and silver from tin by precipitation in a reverberatory furnace with some peculiar fluxes": what success this scheme met with, I have not learnt. Mr. Borlase, in his natural history of Cornwall, gives an account of some tin ore abounding with a yellow matter, which was taken by the workmen for mundic: some bits of the yellow matter, one of which was a vein as large as a goose-quill included in a stone about the size of a walnut, produced, on being melted, an ounce of pure gold: he mentions several other pieces of considerable bulk, and gives a figure of one, found in 1756, weighing three hundred and seventy-six grains. It is supposed to be chiefly the stream tin, (that is the tin ore found in detached pieces on the sides of hills) which contains gold; that all of this sort

contains more or less of it ; and that both the gold and tin ore have been brought from elsewhere by torrents of water, and deposited where they are now found like the gold sands of rivers.

Boyle conjectures, that besides the grains of gold which lie detached among sands, there may be many particles so minute and closely fixed to the sand, as not to be perceivable by the eye, or separable by the common methods of washing or picking ; that many small portions of the metal may be incorporated also with the body of the sand, and that by skilful management they might be extracted. Experiments, he says, confirmed him in this persuasion : later experiments have verified it, and shewn the existence of gold in sands to be even more extensive than he seems to have apprehended. Many of the common sands, particularly the yellow, red, black, and those of a black colour inclining to violet, appear to be rich in gold : Becher and Cramer presume that there is no sand in nature entirely free from it. Hellot relates, that in eleven assays of one kind of sand, made by M. Lieberecht, by a process described in the sequel of this section, the yield of noble metal turned out constantly from eight hundred and forty to eight hundred and forty-four grains on the quintal or 921600 grains, exclusive of what remained in the scoriæ, which were still found to be rich ; that different parcels of sand, taken up at no great distance from one another, differed in degree of richness, some having afforded above a thousand grains, others only three hundred and fifty, and others yielding none by the treatment which had succeeded so well for the rest ; and that of the metal thus obtained from sands two thirds are commonly gold, and the rest silver. Yet notwithstanding the great richness of these sands, no means have hitherto been discovered of availing ourselves

of the metal they contain, or of extracting it to advantage in the large way. Becher indeed undertook to obtain gold with profit from the common sea sands, and entered into engagements with the states of Holland for establishing a mineral work on this foundation : but though experiments made on little quantities promised very considerable gain, and though one trial in large is likewise said to have proved successful, yet, as he communicated the whole process to the commissioners appointed to examine the affair, and as he has shewn that such a work might be carried on more advantageously in Holland than in other parts of Europe, its never having been prosecuted in Holland affords a strong presumption of its not being sufficiently lucrative. The existence of gold in sands is nevertheless an interesting fact, at least to the philosopher, and further examination may perhaps find means of making it turn to account.

Though gold has been but lately discovered, or expected, in these minerals, in which it is so common and so plentiful, their unpromising appearance having given little encouragement to examine them ; there are others, whose flattering colour has raised great expectations, but which have not been found upon experiment to yield any gold. The yellow pyritæ or marcasites, and other minerals of a golden colour, or containing gold-coloured specks, have by some been regarded as ores or matrices of gold, and accordingly submitted to different operations, as fruitless as expensive : their losing their colour in the fire, or changing it to a yellow, soon discovers that their tinging matter is not gold, but sulphur or a ferruginous calx. There are indeed pyritæ which contain gold, and in quantity sufficient to deserve notice : Henckel, in the 12th chapter of his *pyritologia*, gives an account of some assays of minerals of this kind brought from the Hungarian  
mines,

mines, one of which yielded, on the centner or 1600 ounces, half an ounce of noble metal, of which one fifth was gold and the rest silver : from the same quantity of another he obtained no less than sixty ounces of silver, and eight ounces and a half of gold : but the gold, as he observes, is by no means proper to the pyrites, or an essential part of its composition, having been only casually intermixed, as it is in stones and other minerals in the gold mines.

Many have been deceived also by some of the talcs : of which there is one species, naturally of a grey colour, which in a moderately strong fire changes to a gold yellow ; and another, naturally of a glittering gold colour, which receives no change from moderate fire : both these bodies have a further resemblance to gold, in imparting a deep yellow tincture to strong aqua regia. By repeated digestion in fresh aqua regis, all the colouring matter may be extracted, and the earthy part left white : but the solution yields no gold, and is found to be no other than a solution of iron. Reaumur observes that spangles of the yellow talc are frequent in the sands of some rivers, and that they may readily be distinguished from gold, which they have often been taken for, by viewing them with a magnifying glass ; the gold particles found in rivers being constantly smooth, with the edges rounded, while the talky ones are rugged and sharp-edged.

## II. *Separation of gold from earthy and stony bodies by water.*

GOLD intermixed with earthy bodies in small particles or dust, is separated by washing with water, which carries off the lighter earth, and leaves the more ponderous metal behind : the great gravity of gold renders it better adapted to this way of separation than any of the other metals. There are sundry variations in the manner of  
conduct-



conducting the process, according to the quantity of the matter, the nature of the earthy body, and the convenience of the place; many of which are minutely described by Agricola in his treatise *de re metallica*: it will be sufficient here to give a general idea of the manner of procedure, in an operation merely mechanical, and whose success depends chiefly on manual dexterity acquired by practice.

Where the quantity of matter is small, it is laid by a little at a time in a round shallow dish called a buddle, or in an oblong vessel like a boat, which being gently shaken backward and forward, in a tub of water, the lighter part of the earth is taken up and washed off, leaving with the gold such sand or small stones as the mixt contained. By dextrously repeating the agitation, that the whole may acquire as it were a kind of fluidity, the metalline particles sink to the bottom, and the sand or stones are thrown up to the top, and may be removed by the hand.

At several of the gold mines of the Spanish West Indies, the gold is completely separated by this simple operation. According to D'Ulloa's account, in his voyage to those parts, the earth, as it comes from the mine, is thrown into a reservoir, a stream of water conducted on it, the whole stirred together, and the muddy water let off into another and another reservoir: what the water leaves in the first reservoir, and what it deposits in the others, is taken up in trays, or buckets with two handles, and agitated in fresh waters, with an uniform circular motion, till the gold is collected at the bottom.

M. de Reaumur, in the French memoirs for the year 1718, gives a particular description of the method of washing the gold sands of the Rhine and some other rivers. A board, five feet long, a foot and a half wide, with a ledge at each side, and at one end, is laid aslope,

with this last end on the ground, and the other raised a foot and a half: across the board are nailed three pieces of rough cloth, about a foot wide, and at distances of a foot; and at the upper end is placed a kind of basket made of rods. The sand is shovelled into the basket: water thrown on it washes the sand through, the stones remaining: the earth and lighter parts of the sand are carried down to the bottom of the board, while the particles of gold, and the heavy black and red sands already mentioned, are detained by the rough cloths, which, when they appear covered, so as not to be able to detain more, are taken off and washed in a tub of water, then nailed on again, and the process continued till a proper quantity of this richer sand is obtained. In some places, instead of cloths, skins with the hair or wool on are used; and in others, notches are made across the board. The richer sand thus detained is put into a vessel somewhat like a boat, which is gently shaken in water, in the same manner as the fan in winnowing corn, till the lighter grains rise to the top: these being carefully poured off with the water, the agitation is repeated so long as any grains, of a different colour from the rest, are found to rise. No further separation is to be expected by this method, and the gold, of which some particles begin now to be distinguishable by the eye, is extracted from the remaining matter by mercury, as described in the following article.

Gold bedded in stones may frequently be separated from great part of the stony matter on the same principle, the stone being previously reduced to powder. In the large way it is beaten in mills, under water, by large wooden stampers armed at the bottom with iron, an iron grating being commonly fixed at one side of the trough or pit, through which the finer parts are continually washed

washed off by the water. When a little quantity is to be powdered in a mortar, it should likewise be done by blows of the pestle, not by grinding: a blow only flattening the metalline particles, while triture wears and divides them, in part, to such tenuity, as not freely to subside in water. Stones of the hard flinty kind are previously made red hot, and quenched in water; by which means they are rendered more easily pulverable, and at the same time many of the small particles of gold, melting in the fire, unite and form larger masses.

### III. *Separation of gold from earths and stones by mercury.*

WHERE the minuteness of the particles of gold, and the weight of the matter with which they are intermixed, renders them inseparable by water, quicksilver is called in aid for imbibing and detaining the gold. The gold sands, freed by water, as in the foregoing article, from as much of the lighter matter, as can be washed off by water without endangering a great loss of the gold, are dried, and a small proportion, less than a hundredth part of their weight, of mercury poured on them: the whole is well kneaded up together, that the mercury may penetrate, as much as possible, into all the interstices between the grains; it imbibes the atoms of gold it meets with, and the sand is afterwards washed off by water.

In the Spanish West Indies, at those mines where the gold is bedded in stones, and requires quicksilver for its separation, the stony matter is reduced to as fine powder as possible, that every atom of the gold may be laid open to the mercury. The powder is soaked for some time in a solution of common salt; the mercury squeezed in through a linen cloth, so as to fall like dew all over the surface; and the mixture being well stirred and

kneaded, a gentle heat is applied, by which the activity of the mercury is so far increased, that the incorporation of the gold with it, which in the cold requires about thirty days, is said by J. Hernandez, in an essay on these mines, to be effected by this method in five or six days.

Alonso Barba, in the third book of his art of metals, describes another method, which he says he has practised with great advantage : he puts the powder, with a suitable quantity of mercury and water, into a deep copper vessel fixed in a furnace, and applies a fire sufficient to keep the water boiling : a small wooden mill assists the ebullition of the water in giving motion to the earthy powder, which continually rising and falling down again, is brought into frequent contact with the mercury at the bottom, so as to give out its gold to the mercury in as many hours, as the common process without heat requires days.

When the gold is judged to be united with the mercury, the earthy powder is washed off by water, so as to leave the amalgam clean. Where the mercury has been kneaded up with the powder, a considerable part of it is always divided into such minute globules as to be washed away along with the earth ; an inconvenience which in the other method does not happen or in a far less degree.

The gold dust or filings dispersed through the sweepings of the goldsmiths shops, are recovered also by amalgamation with mercury. Two broad iron bars, rounded at the ends, placed crosswise and fixed on an upright axis, are made to turn, by a handle at the top, on an iron plane fitted into the bottom of a tub. The sweepings being put into the tub with a quantity of mercury and water, the powder, passing successively under the iron bars, is ground and brought into contact with the quicksilver, which by degrees extracts the gold ; while the water, which after a certain time is suffered to run off through a small quill

quill in the side of the tub, carries with it the lighter earthy matter: fresh water is supplied till all the earth is thus washed off. The operation might doubtless be expedited by the use of heat, as in the above process of Barba.

The gold being by these means transferred into the mercury, and the mixture washed clean, as much as may be of the mercury is pressed out through leather, and the remainder forced off by fire. To collect the exhaling mercury, a head and receiver are fitted to the iron pot in which the mass is exposed to the fire: Barba advises the pot to be lined with a mixture of clay and sand, to prevent the gold from adhering to or dissolving a part of the iron in case the fire should be raised so far as to make the gold melt.

It is scarcely to be expected, that the greatest address of the workman can collect, either by water or mercury, the whole of the gold diffused through a large quantity of other matter; at least when the mercury is used, as it is in the large way, in so small a proportion as a hundredth or a two hundredth part of the weight of the earthy powder. Reaumur, after having worked some gold sand with mercury, in the method commonly practised by those who wash the sands of rivers, obtained, from the remaining sand, by treating it with a double quantity of mercury, near as much gold as he had done the first time.

#### IV. *Extraction of gold intimately combined in the composition of sands.*

FOR extracting gold from the ferruginous sands mentioned in the preceding part of this section, the sand is to be made red hot and quenched in water, and the ignition

and extinction repeated four times or oftener. The colour changes, from yellow, red, or black, to a reddish brown. In the first and second heating, the sand yields a slight smell, somewhat like that of garlick, a mark of its containing arsenic : at the third time, the arsenical smell is scarcely to be perceived, but on throwing into the crucible a little tallow, or other like inflammable matter, it becomes stronger than before : this remarkable circumstance is by no means peculiar to these sands, for there are several arsenical minerals which give out little of their arsenic in the fire till some inflammable matter is added. The sand, thus calcined, is mixed with twice its weight of granulated lead, and equal its weight of black flux, the mixture put into a crucible, and covered with some sea salt dried over the fire till it has ceased to crackle. The crucible is placed in a good blast furnace, the fire strongly excited, and the matter stirred from time to time with an iron rod : the fire must be urged till the scoria flows thin as water, which is known by the rod coming out almost clean, without the least knob sticking to the end of it. The crucible is then suffered to cool, and broken for getting out its contents : on the top is the common salt, in a distinct cake ; under this, a shining black, compact, vitreous scoria ; and at the bottom, a lump of lead, easily separable from the scoria. The gold, contained in the sand, is now transferred into the lead, and may be separated by working off the lead upon a cupel or test. These sands contain also silver, which here accompanies the gold, and which may be parted, after the cupellation, either by aqua fortis or aqua regia, according as one or the other metal appears to prevail in the mixt. This is the process followed by M. Liebericht in the assays already given an account of.

As the black flux (which consists of one part of nitre, and two or three of tartar, mixed together, and burnt in a covered vessel to a black alkaline coal) is apparently too expensive to be employed for any considerable quantities of the mineral; its place may be supplied by a mixture of potash, or other fixt alkaline salts, with powdered charcoal. Four parts of potash, three of charcoal, and thirty-two of lead, are sufficient for sixteen of the calcined sand. This mixture, as Hellot observes, requires the fire to be continued longer than the preceding to make the matter equally fluid; but when it is made so, the yield is found to be in both cases alike.

The same end may be obtained also, by boiling the calcined sand in melted lead, without any inflammable or saline addition. For the vitreous matter, into which the lead is gradually converted, will dissolve the earth, and the unvitrefied part of the lead will receive and collect the gold; but a much larger quantity of lead is requisite in this than in the other ways.

In all the foregoing methods, though the quantity of gold obtained is considerable, much still remains in the scoriæ, from want, probably, of a thorough commixture of them with the lead: for whatever degree of fluidity the scoriæ are brought to, the particles of gold are too minute to subside by their own weight, and the lead can collect them only from those parts which it comes in contact with. It may therefore be presumed, that the separation will be the more complete, as the commixture of the lead is the more perfect. Lead cannot be mixed perfectly with sands but in a vitreous or semivitreous form. By grinding the calcined sand with litharge or other calces of lead, and exposing the mixture to a moderately strong fire, they may be intimately united into an uniform glassy compound; the sand being dissolved by the vitrefied lead,

nearly as salt is dissolved by water. On adding to this compound a little powdered charcoal, or barely stirring it with an iron rod, the lead revives and falls to the bottom; and as the sand had thus been in contact with every part of it, the gold will probably be extracted from every part, or at least more effectually than by the other methods. In this way it will be proper to mix some alkaline salt with the litharge and sand; partly, to promote the dissolution of such portion of the sand as floats on the top of the ponderous metallic preparation; and partly, to continue the fluidity of the scoria after the revival of the lead. The crucible may be made of Sturbridge clay, which seems to be one of the best, of the common materials, for resisting glass of lead in fusion. It appears to have been on a process of this kind, that Becher's proposition to the States of Holland was founded, for extracting gold with profit from common sands; it is plain from his account of this affair in his *minera arenaria*, that he vitrified the sand with glass of lead, or litharge, and he expressly mentions in one place the precipitation of the lead from the glass by iron: he used also an addition of silver, in great proportion, for imbibing the gold, and thus required a vast capital for establishing a work in large; but where the lead is to be revived, the silver is rather detrimental than useful; for the gold and silver contained in the sand are imbibed by the lead, and the additional silver occasions an enormous expence of aqua fortis for dissolving it in order to the separation of the gold. Whether, with this reduction of the expence, of which Becher himself seems to have had some idea, the process might be practicable to advantage, or whether some earthy bodies might not be an useful auxiliary for promoting the fusion of the gold sands, may deserve further enquiry: one kind of earth is frequently observed to



bring another into fusion, though both are of themselves unfusible ; and the earthy parts of different ores are made fluid in the furnace of the smelter by the addition of other earths.

V. *Extraction of gold from the ores of other metals.*

WHEN gold is intimately combined with other metals in their ores, the ore is to be run down in the same manner as the same kind of ore without gold. The gold commonly melts out with the proper metal of the ore, from which it may be afterwards separated by different processes according to the nature of the metal. There are grounds to believe that most metallic bodies, as extracted from their ores, contain generally a portion of gold, though rarely sufficient to bear the expences of its separation.

Zinc, arsenic, and mercury, are obtained from their ores by a kind of sublimation : hence if the ores of these contain gold, the gold is to be sought for, not in the metallic substance separated, but in the remaining matter. There are some other cases also, in which the gold, instead of accompanying the metal in its fusion, is thrown off in the slag : but the ores and slags of this kingdom have been so seldom examined for gold, that at present I can say little satisfactory on this subject.

S E C T. XII.

*Of the alchemical history of gold.*

SOME of the Greek writers, in the fourth and fifth centuries, speak of an art, as being then known, of transmuting the baser metals into gold ; and towards the end of the thirteenth century, when the learning of the east had been brought hither by the Arabians, the same pretensions

pretensions begun to spread through Europe. It has been supposed that this art, called alchemy, was of Egyptian original ; and that, when the ancient Greek philosophers travelled into Egypt, they brought back some of the allegoric language of this Egyptian art ill understood, which afterwards passed into their mythology. This is all that is known with certainty, or can be admitted with any shew of probability, about the origin of an art, whose history and antiquity have been the object of elaborate researches, and treated with a profusion of erudition.

Alchemy was the earliest branch of chemistry considered as a philosophic science. In the other parts of chemical knowledge, facts preceded reasoning or speculation ; but alchemy was originally speculative. Such of the alchemical writers as are reckoned of most authority, as Geber, Hollandus, and others, declare, that we are not to hope for success in the practice of this work, without being previously well acquainted with the nature, essence, and principles of metals ; whence they were produced in the mines ; whence they receive their increase ; how and to what state they have a natural disposition to be brought, and would have been brought if it had not been for some impediment ; and what these impediments are.

The alchemists supposed that nature, in all her works aiming at perfection, in producing metals aimed at gold : that the imperfect or base metals failed of being gold, either from a redundancy or deficiency of some particular element in their composition, or for want of sufficient coction, maturation, or depuration of their principles ; and that art could correct or remove these impediments, so as to complete the work which nature had begun.

They supposed the general principles of metals to be chiefly two substances, to which they gave the names of mercury and sulphur ; and that of both these there were  
different

different kinds, particularly of the latter ; which they admitted as many varieties of as there are metals ; and which, in gold, they held to be pure, red, fixt and incombustible, but of different qualities in the other metals. In these points there is no perfect uniformity among the different alchemical philosophers, which indeed could not be expected in hypotheses on so abstruse a subject, where experience had afforded so little light : some have added a saline, some an earthy, and others an arsenical principle.

They supposed that the pure mercurial, sulphureous, or other principles of which they imagined gold to be composed, were contained, separately, in certain other bodies. These principles therefore they endeavoured to collect, and to concoct and incorporate by long digestions. In the many volumes written professedly to teach the process at full length, the subjects, from which the golden seeds are to be obtained, are wrapt in impenetrable obscurity : thus much is plain, that the supposed adepts in this mysterious science do not all make choice of the same subjects, or work upon them in the same manner, their practice being probably adapted to their particular hypotheses.

By thus conjoining the principles of gold, if they could be so procured and conjoined, it might be expected that gold would be produced. But the alchemists pretend to a product of a higher order, called the elixir, the medicine for metals, the tincture, the philosophers stone ; which, by being projected on a large quantity of any of the inferior metals in fusion, should change them into fine gold ; which, being laid on a plate of silver, copper, or iron, and moderately heated, should sink into the metal, and change into gold all the parts it was applied on ; which, on being properly treated with pure gold, should change the gold into a substance of the same nature and virtue with itself, so as thus to be

ſuſceptible of perpetual multiplication ; and which, by continued coction, ſhould have its power more and more exalted, ſo as to be able to tranſmute greater and greater quantities of the inferiour metals, inſomuch that, according to its different degrees of perfection, one part of it ſhall be ſufficient for ten parts, a hundred parts, a thouſand parts, twenty thouſand parts, two hundred and ſeventy two thouſand three hundred and thirty parts of baſe metal.

If theſe pretenſions were propoſed as matter of ſpeculation only, I believe no one, who has at all conſidered the nature of metals, could heſitate in pronouncing them abſurd : they are inconſiſtent even with the alchemical philoſophy itſelf. But they are endeavoured to be ſupported by arguments of another kind ; by historical relations of the actual tranſmutation of all the common metals, ſtrongly atteſted, not only by the alchemiſts themſelves whoſe teſtimony might be thought ſuſpicious, but likewiſe by perſons ſuppoſed to have been entirely unprejudiced, who had been caſually favoured with ſome quantity of the tranſmuting powder, or who had been witneſſes to its aſtoniſhing operation and to the immenſe riches it had procured.

In regard to theſe narratives I ſhall only remark, that at a time when the tranſmutability of metals was generally believed, the circumſtances of certain princes might render it an advantage to them to be thought to have ſuch an inexhauſtible reſource for wealth : that ſome perſons who, by methods which it was their intereſt to conceal, had acquired ſudden riches, might, in this art, find plauſible means of giving an account for them ; that many of the ſuppoſed alchemiſts have been convicted, and perhaps many others guilty, of impoſture ; the gold, which they pretended to have made, having ſometimes

sometimes been previously concealed in the crucible, or in the materials, or at the end of the rod, with which the matter was stirred in fusion, and sometimes introduced into the crucible by a confederate, when the furnace was covered, through an aperture communicating with another apartment. So many frauds and juggling artifices are known to have been practised on this occasion, that the evidence of a spectator can be of no force; and perhaps those, who were more than spectators, were too much interested to be admitted as evidences.

I am very far, however, from censuring as impostors all those who have declared themselves convinced, from their own experiments, of the transmutability of base metals into gold. Many experiments have been alledged, in which base metals were made to yield some portion of gold, and in which gold, treated with certain additions, received an increase: though the quantity obtained was rarely such as to bear the charges of the process, it is reckoned sufficient at least, in a philosophic view, to demonstrate the actual transmutation, into gold, of a substance which before was not gold. Most of these experiments are free from suspicion of any fraudulent design; but there are strong reasons to suspect that the authors have been themselves deceived by fallacious appearances.

Gold, as we have already seen, is now known to be far more frequent in metals and other minerals, than it was formerly supposed to be; and there is little wonder, if men of warm imaginations, biassed by a favourite hypothesis, have been led to believe that they produced gold when they extracted it from materials in which it was not imagined to præexist. We have seen also, in a foregoing section of this essay, that the common method of parting silver from gold by aqua fortis does not com-

pletely separate the silver; and it has often happened, that when fine gold, melted with silver, was submitted to certain operations, and afterwards parted, the portion of silver which the aqua fortis left in the gold, has been taken for an augmentation of the gold itself. Of this I knew a remarkable instance in a process which was some years ago referred to my examination, and whose success was averred to have been such, that it was offered as a very lucrative operation, and a considerable price demanded for the communication of it: the gold, after it had passed through the tedious process that was to enrich it, and had been parted from the silver by weak aqua fortis, according to the directions, weighed indeed notably more than the pure gold employed: but on reducing it to its former purity by solution in aqua regis, I found it reduced at the same time to its former quantity. It is probable that many of those, who have been most sanguine in their expectations of gain from alchemical operations, had no other foundation than these misunderstood kinds of experiments; which having once persuaded them that they could make gold, they might naturally conclude that it could be made in any quantity. I shall only further remark on this head, that if a part of the substance of any metal was by any operation transmutable into gold, a part more would be in like manner transmutable by a repetition of the operation, and this successively, so long as any part of the metal remained entire and perfect, or so long as it retained the properties which it had at first: a process of this kind would be decisive, but such a process has not yet been made known.

The destruction of gold is affirmed by the alchemists to be more difficult than its production. This point also has been eagerly prosecuted, not only on account of its being interesting as an object of philosophy, but on ac-

count likewise of some advantages expected to result from it, many having persuaded themselves that its destruction or resolution would afford the sure foundation for its artificial production. Divers experiments have been alledged, in which gold is said to have been destroyed, or changed into a matter which was no longer gold, or resolved into dissimilar principles : but in these experiments, as in those of its production, there was probably some deception ; and many of them, as related by the authors themselves, are apparently inconclusive.

Mr. Boyle gives an account of a process, by which he imagines part of the substance of gold to have been transmuted into silver. Into rectified butter of antimony, that is a solution of the metallic part of antimony in the marine acid, he poured as much spirit of nitre as was sufficient to precipitate the metal, and having distilled off all that would come over in a smart fire, he returned the liquor on the antimonial powder, and abstracted it again : of this menstruum, which is a kind of aqua regia, he had a great opinion, and gave it the name of *menstruum peracutum*. Some gold was melted with three or four times its weight of copper, the copper extracted by aqua fortis, and the remaining gold powder being brought to its due colour by heat, a large proportion of the menstruum was poured on it : the gold dissolved slowly and quietly, and there remained at the bottom of the glass a considerable quantity of white powder. The solution of gold being abstracted, and the gold again reduced to a body and dissolved a second time, it yielded more of the white powder, but not so much as at first. On melting these powders with borax, he obtained a white metal, which yielded to the hammer, and which, on being dissolved in aqua fortis, shewed itself, by the odious bitterness

ness it produced, to be true silver. He says, that even with good aqua regis, he could obtain from the very best gold some little quantity of such a white powder, but in so very small proportion, that he never had enough at once to make him think it worth while to prosecute such trials.

It were to be wished that the ingenuous author had been more careful in ascertaining the purity of the gold made use of in these experiments, and noted the exact quantity of silver obtained from it. Gold parted from silver or copper by aqua fortis, is by no means to be looked upon as being pure : nor is there perhaps any other method, as yet known, of perfectly purifying it from silver, than that by which the silver was separated in the above experiments ; the dissolution in aqua regia being in effect no other than a purification of the gold. Even aqua regia, when made with an under proportion of marine acid, will not produce a complete separation ; this imperfect aqua regia taking up, along with the gold, a little silver, separable by a second dissolution.

Mr. Boyle has given an account also of a very extraordinary experiment, under the title of the degradation of gold by an anti-elixir, which was published in his own life time, and since reprinted in 1739. The known character of the author, the earnest desire he has shewn in all his writings for the discovery of truth and the exposing of false pretences, have not only rendered the fact unquestionable, but likewise induced many to adopt the consequences which he thought might be drawn from it ; and to regard it as a proof of the real alterability of gold, and as strongly favouring the alchemical doctrine of the transmutability of metals. I shall therefore insert the account of the experiment in the author's words, and subjoin a few remarks ; lamenting that it is not in my power



to enquire more satisfactorily into so curious a fact by a repetition of the experiment. The substance, by which the apparent degradation was produced, was a powder of unknown composition, communicated to Mr. Boyle by a stranger, and its quantity not sufficient for more than a single trial. There was so very little of it, that he could scarce see the colour of it, save that, as far as could be judged, it was of a darkish red : the quantity was estimated at an eighth or a tenth part of a grain. The gold had been formerly English coin, and to be sure of its goodness, he caused it to be, by one whom he usually employed, cupelled with lead, and afterwards quarted with refined silver and purged aqua fortis. Two drams of this gold, thus purified, were weighed out, and put into a new crucible first carefully nealed, and the gold being brought into fusion, without addition, he put into the well-melted metal the little parcel of powder with his own hand, continuing the fire about a quarter of an hour, that the powder might have time to diffuse itself every way into the metal : the well-melted gold was then poured out into another crucible, which had been gradually heated to prevent its cracking. But though, from the first fusion of the metal to the pouring out, it had turned in the crucible like ordinary gold, save that once, as the assistant observed, it looked for two or three minutes almost like an opal : yet when the matter was grown cold, though it appeared on the balance that it had not lost any thing of its weight ; yet, instead of fine gold, there was a lump of metal of a dirty colour, and as it were overcast with a thin coat almost like half vitrefied litharge : to one side of the crucible there stuck a little globule of metal, that looked not at all yellowish, but like coarse silver ; and the bottom of the crucible was overlaid with a vitrefied substance, whereof part was  
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of a transparent yellow, and the other of a deep brown inclining to red : in this vitrefied substance there were plainly perceived sticking at least five or six globules that looked more like impure silver than pure gold. Having rubbed this odd metal upon a good touchstone, whereon there was likewise rubbed a piece of coined silver and a piece of coined gold, the mark left by it on the stone was notoriously more like that of the silver than of the gold. Having knocked the little lump with a hammer, it was found brittle, and flew in several pieces. Even the insides of those pieces looked of a base dirty colour, like that of brass or worse, for the fragments had a far greater resemblance to bell-metal than either to gold or silver. One dram being carefully weighed out, and put on an excellent new and well-nealed cupel, with about half a dozen times its weight of lead ; though it turned very well like good gold, yet it continued in the fire above an hour and a half, which was twice as long as was expected, and yet almost to the very last the fumes copiously ascended, which sufficiently argued the operation to have been well carried on ; and when at last it was quite ended, the cupel was found very smooth and entire, but tinged with a fine purplish red ; and, besides the refined gold, there lay upon the cavity of the cupel some dark coloured recrements, which were concluded to have proceeded from the deteriorated metal, not from the lead. But when the gold was put again into the balance, it was found to weigh only about fifty-three grains, and consequently to have lost seven ; which yet was found to be fully made up by the recrements abovementioned, whose weight and fixity, compared with their unpromising appearance, did not a little puzzle the ingenious author, especially because he had not enough either of them, or of leisure, to examine their nature. The ill-looking mass,  
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before it was divided for the cupelling, was weighed in water, and instead of weighing about nineteen times as much as a bulk of water equal to it, its proportion to that liquor was but that of fifteen and about two thirds to one; so that its specific gravity was less by about three and a third than it would if it had been pure gold. From this experiment the author concludes, that an operation very near, if not altogether, as strange as that which is called projection, and in the difficultest points much of the same nature with it, may be safely admitted: for the experiment plainly shews that gold, though confessedly the most homogeneous and least mutable of metals, may in a very short time be exceedingly changed, both as to malleableness, colour, homogeneity, and what is more, specific gravity; and all this by an inconsiderable proportion of injected powder, not amounting, on the modestest estimate, to a nine hundred and fiftieth part of its weight. He adds, that there is a still stranger effect of this admirable powder, which he has not mentioned because he must not do it.

On this history it may be remarked, 1. That little dependence can be had on the conjecture of the weight of the powder, as it might possibly not be all distinguished on the paper it was wrapt in, and as different kinds of bodies have different weights under equal volumes. 2. If no mistake was made in weighing the metal after the fusion, the quantity of powder must have been greater than was imagined; for the lump of metal appeared to weigh as much as the gold employed, exclusive of the vitrified substance which the bottom of the crucible was overlaid with, and of the metallic globules that adhered to it. If these globules had been picked out, or separated by pounding and washing the pieces of the crucible, and weighed with the lump, it is scarcely to be supposed that

the author, so minute in his details, would have omitted such a circumstance; and besides, repeated experience has convinced me, that when gold, from any admixture, has contracted a vitreous coat, and any small grains of it stick about the crucible by means of this coat, the grains cannot by these methods be completely collected. 3. That the gold employed was fine, and that its specific gravity was nineteen, was only supposed. The author himself appears to have suspected its purity, for he says that to remove scruples on this head he caused a dram and a half of it, which had been purposely reserved, to be melted in his assistant's presence, and found it fine and well-coloured; but surely the colour of the mass cannot be admitted as a sufficient criterion of its purity. Indeed it could not have been entirely pure; because, though it had been so at first, yet the process of parting, however carefully performed, would have left some silver in it. 4. Admitting the gold to have been perfectly fine, and no error to have happened; it will not follow that the gold was degraded or altered in its nature, or that the experiment gives any countenance to the pretensions of the alchemists. Gold is strongly affected, in many of its properties, by the admixture of very small proportions of certain other bodies: a quantity of tin, less even than that which the foregoing powder is supposed to have amounted to, renders gold brittle. It is plain that at least fifty-three parts in sixty of the gold in the above experiment were in like manner debased only by the coalition of another matter with it, and that this extraneous matter was separable by simple cupellation with lead. The history affords no reason to believe that the remainder of the gold might not also have been recovered, by suitable management, from the ponderous fixt recement: for gold has frequently been found debased and disguised by substances which resisted

refisted cupellation, and which have afterwards been separated by other processes. An instance of this has been already mentioned in the ninth section, and a more remarkable one is given by Homberg in the memoirs of the French academy for 1693 : a quantity of gold, after cupellation, quartation, fusion with antimony and the distillation of the antimonial metal, and repeated fusions with nitre, continued quite brittle though of a high colour : by treating it again with antimony and lead, and working off the superadded metals on a cupel, it lost its colour also, and became grey, but by further repetitions of the fusion, both its colour and malleability were at length restored.

Juncker reports from Borrichius and Oslander, that on grinding for a length of time, in a glass mortar, an amalgam of one part of gold and four of mercury, with distilled water, there separates daily a black matter, which may be collected by pouring off the water and suffering it to settle : that after the triture has been continued for some weeks, the water yields, on being evaporated, some granules of a crystalline salt : that the black powder yields, on fusion, a green glass ; and that the metal is thus resolved or destroyed. But mercury alone by continued triture or agitation, is changed into a similar powder ; of which a part abides fixt in a considerably strong fire : the vitrefication probably proceeded from some particles abraded from the glass mortar ; and the saline matter, the proportion of which is acknowledged to have been very minute, either præexisted in the water or was extracted from the glass. Borrichius himself affords a strong presumption that the black powder proceeds rather from the mercury than from the gold : after some days, he observes, the amalgam grows stiff, and the separation more sparing, and therefore fresh mer-

cury is directed to be added. I have continued the trituration of an amalgam of gold, almost incessantly, for more than a week, and afterwards recovered the gold entire.

. Kunckel imagines, that when glass is tinged red by Cassius's precipitate or other preparations of gold, the particles of the metal are not barely diffused through the glass, but resolved into their elementary parts, so as no longer to be reducible into gold again. He might indeed fail of recovering the gold; but though no means were known of separating so small a proportion of it from so large a quantity of vitreous matter, it surely could not follow that the gold was destroyed.

Some other processes, proposed for the destruction of gold, have been already taken notice of. It has been shewn, that the vehement heat, collected in the focus of large burning glasses, and the long continued action of a gentle heat, do not, so far as can be judged from the facts as yet known, make any real change in it; and that the much boasted volatilization of gold does certainly not destroy it, since the volatilized gold may with ease be restored to its fixity and all its former qualities.

Upon the whole, both the producibility and destructibility of gold continue still problems in chemistry. I know of no experiment from which the possibility of either can be inferred; and to demonstrate their impossibility is beyond the reach of experiments.

But though those, who have laboured the most ardently in these pursuits, instead of acquiring, have generally exhausted riches, and may on good grounds be presumed to have missed of their principal aim; yet justice requires us to add, that their labours have not been altogether useless, and that many valuable discoveries, relative to different subjects, have resulted from their enquiries. It  
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is to be regretted, that their affected mysteriousness, and peculiar mode of philosophizing, have rendered their writings so forbidding, that many useful facts, scattered through them, lie still unknown.

### S E C T. XIII.

#### *Imitations of gold.*

##### I. *Gold coloured metal.*

**F**ROM the general estimation of the colour of gold, which has attracted the notice of the most barbarous nations, the communication of the same admired colour to metals of low price, for uses where the other qualities of gold are not required, becomes an important object. The production of a kindred colour, by artificial composition, in the common metal brass, affords a principle for this imitation.

Brass is prepared by melting copper with the mineral called calamine, from which it receives an increase of one third or one half its weight. The matter, which the copper imbibes from the calamine, is found to be zinc, of which that mineral is properly an ore; and accordingly zinc itself, melted with copper, communicates a colour of the same kind. According to the purity of the zinc and copper, the proportions in which they are mixed, and the intimacy of their union, the compound metal proves more or less malleable, and approaches more or less to the colour of gold.

Those who have given receipts for making a gold coloured metal, differ greatly in the proportion of the two ingredients; some directing the zinc to be taken only in a fifth or a sixth part of the weight of the copper, and others in an equal weight or more. From a set of ex-

periments made to determine this point it appeared, that there is some foundation on both sides; and that, both with the smallest and the largest of these quantities of zinc, the metal proves more like gold than with the intermediate proportions.

One part of zinc and three of copper formed a compound of a brassy yellow colour, but rather brighter than common brass, and at the same time more brittle: when broken, its texture appeared partly fibrous, and partly grained.

On increasing the quantity of copper to four, five, six, eight, and ten times the weight of the zinc, the metal proved more and more tough, of a fine grain without any appearance of fibres, and its yellowness more and more mixed with a reddish cast, like that of gold alloyed with copper. The best coloured mixture, obtained by an augmentation of the copper, consisted of five parts of copper to one of zinc: even this, however, differed greatly in colour from fine gold. A mixture of ten parts of copper and one of zinc looked like gold somewhat worse than standard, and hammered extremely well.

On diminishing the proportion of copper, from thrice, to double, equal, and two thirds of that of the zinc, the colour was improved much more than by an augmentation of it, the compounds proved much more brittle, and wholly of a fibrous texture, without any appearance of grains: they broke over short on trying to bend them, and fell in pieces under the hammer. Equal parts of copper and zinc, or a little more zinc than copper, seemed to produce the finest colour: these mixtures, in the mass, had a near resemblance to pure gold; though strokes drawn with them on a touchstone were remarkably paler, looking almost white when compared with those of the gold. And indeed all the compositions I have examined,  
whether



whether made by myself or others, how nearly soever they approached to gold in the mass, were very different from it on the touchstone.

The colour of these compounds is improved by a small admixture of certain other metallic bodies. Cramer observes, that when copper is melted with a fourth or a sixth of zinc, and a little pure tin; the compound metal, well cleaned and laid in the air for some days, acquires on the surface the colour of fine gold: this teint, though merely superficial, is not the less valuable; for though it should be discharged by cleaning, the piece soon recovers it again, every fresh surface tarnishing as it were to a like colour. Geoffroy relates, in the French memoirs for the year 1725, that on trying different metals, iron seemed to have the best effect: equal parts of copper and zinc being brought into fusion, he threw in some iron filings, amounting to an eighth part of each of the other metals: the mixt turned out of a beautiful yellow colour, and a fine smooth grain, not at all fibrous, as mixtures of copper and zinc in this proportion by themselves always are, yet very brittle: on repeating the experiment with a fourth more of zinc, the proportions being ten parts of zinc, eight of copper, and one of iron filings, the metal proved of a grain like the former, but more compact, harder, brighter, and in colour still more like gold. He says the commixture of the iron with the other ingredients requires a particular management, which I cannot find that he has any where communicated.

It has been said, that the mixtures of zinc and copper may be made tough, by injecting upon them in fusion a little mercury-sublimate, as also by nitre, sal ammoniac, borax, and different kinds of inflammable bodies: but these additions, as I have often found from experience, and as Pott also observes in a dissertation *de zinco*,

will not answer. The great brittleness has been generally imputed to the lead, of which the common sorts of zinc are supposed to partake in a greater or less degree; and hence it has been supposed necessary to previously purify the zinc, by cementation and fusion with sulphur, which absorbs and scorifies the lead without acting upon the zinc: some sorts of zinc may doubtless require a treatment of this kind, but such, as has been usually brought from the East Indies, does not seem, when prepared in this manner, to give less brittleness than when unprepared.

It is certain, however, that copper impregnated with zinc, by cementation and fusion with calamine, proves more malleable, than when melted directly with as much of common zinc itself as it imbibes from the calamine; on account, perhaps, of the commixture being in the first case more equal and perfect. By the process with calamine, copper cannot easily be made to receive the full quantity of zinc necessary for producing a good gold colour: by combining the two processes together, that is by making the copper first into brass, and then melting it with a suitable quantity of zinc, a metal may be obtained of better quality than by either method singly. A very ingenious artist, who now prepares a gold-coloured metal in great perfection, has a fine kind of brass made on purpose for this use. An enquiry into the preparation and improvement of brass will make a separate article in one of the future numbers of this work.

A good deal of address is requisite in melting the copper and zinc together; for the heat necessary for the fusion of copper occasions the zinc to burn and flame, and a considerable part of it to be dissipated, so that the remaining copper is defrauded of its due proportion. If the two metals are put into the crucible at first, and the fire gradually raised, greatest part of the zinc will be burnt off  
before

before the copper melts: if the copper be first melted by itself, and the zinc heated and plunged into it, a strong commotion ensues, though the dissipation is much less considerable than in the other case, the zinc being quickly imbibed by the melted copper and in some measure protected and retained by it: if the copper and zinc be brought separately into fusion, and one poured into the other, an explosion happens, and great part of the mixture, in my experiment above two thirds of it, is thrown about in drops, to the great danger of the bye-stander. The union appeared to succeed best, and with least loss of the zinc, when fluxes, containing inflammable matter, were added: I have generally used a mixture of black flux and borax; to which may be substituted a cheaper composition of twelve parts of green glass in fine powder, six parts of potash, two of borax, and one of powdered charcoal. The flux is first to be brought into fusion in the crucible, and the copper and zinc dropt into it: as soon as these appear perfectly melted, they are to be well stirred together with an iron rod, and expeditiously poured out. The same flux serves repeatedly for the melting of several fresh quantities of the metal.

There are many receipts for making a gold coloured metal, from verdegris a preparation of copper, and tutty a preparation or ore of zinc: the difference, above taken notice of, in the effect of zinc itself and of its common ore upon copper, induced me to try, whether, in this form of combination also, some useful variation might not happen. One of the best of these receipts seems to be that among Hook's papers published by Derham; in which eight parts of distilled verdegris (that is, verdegris purified by solution in distilled vinegar and crystallization) and four parts of Alexandrian tutty, with two of nitre and one of borax, are directed to be mixed with oil to the consistence

of pap, then melted in a crucible, and poured into a flat mould first well warmed. The person, who communicated this receipt to Dr. Hooke, says that the metal will not only appear, but work, like coarse gold; that he sold it as dear as silver; and that the king of Poland had a service of it, only mixing fifteen ounces of gold with a hundred of the compound metal. I tried this process with verdegriſ, which I had myself purified, by dissolving it in distilled vinegar, and evaporating the filtered solution to dryness: a large proportion of the verdegriſ remained undissolved; and this residuum, on being melted with black flux, yielded a brittle pale coloured metal almost like bell-metal: from whence it might be presumed, that the copper, in the inspissated matter, was rendered purer than ordinary by the separation of this extraneous metal. On melting it with choice tutty, and the other ingredients, the result was a very fine metal, which bore the hammer well; but it was rather a fine brass than a true gold coloured metal, its colour having less resemblance to gold than that of the mixture of equal parts of common copper and zinc already mentioned.

Tutty and calamine contain zinc in a state of calx; and hence, in the use of these, inflammable additions are essentially necessary, for reviving the zinc into its metallic form. Some of the earlier writers direct for this purpose substances of a yellow colour, as turmeric, rhubarb, saffron, aloes, which are still used, as I am informed, by several workmen, who do not seem to have considered, that these kinds of substances can be of service no otherwise than as they furnish an inflammable matter, and that common charcoal answers the same end.

Two ways have been recommended, for giving a gold colour to copper, and at the same time preserving its malleability, without the addition of any zinc, or of substances

substances containing it; the one, as is said, by Homberg (for, though given as from him by some late reputable writers, I cannot find it among his papers in the French memoirs) the other by Vigani.

In Homberg's method, the copper is to be amalgamated with pure quicksilver, the amalgam boiled in river water for two hours, the quicksilver distilled off in a retort, and again poured back and abstracted once or twice: the remaining copper, being now fused, is said to appear of a beautiful gold colour, and to be more ductile than common copper, so as to be well fitted for the finer machines and utensils. The great difficulty of amalgamating copper by the common methods seems to have prevented this process from coming to a fair examination. This difficulty I have surmounted in different ways: one of the easiest and most expeditious of which was, by dissolving the copper in aqua fortis, and, when the menstruum would take up no more, pouring the solution into an iron mortar, along with six times as much quicksilver as there was of copper, and some common salt, and then grinding them well together with an iron pestle: the dissolved copper is extricated from the acid by the iron, in a very subtle form, and falling in this state into the quicksilver, is readily imbibed by it. This amalgam was ground and washed with water till it became perfectly bright, and the mercury was then distilled off: the remaining copper, melted in a crucible, had, as was indeed expected, no degree of yellowness, and appeared exactly of the same colour as at first. As no sensible alteration was thus produced, a repetition of the troublesome operation was judged unnecessary.

Vigani's process carries with it strong marks either of error or reserve; yet from the general character of the author, and the favourable reception he met with in this

country, I should not perhaps be held excused if I did not take some notice of it. Copper is to be melted in a crucible, an equal weight of powdered sulphur sprinkled on it, the fusion continued till the sulphur is all burnt off, and the metal afterwards flatted into plates. A quantity of orpiment, *auripigmentum*, is to be melted and quenched in vinegar, and the fusion and extinction repeated twenty-four times. The materials being thus prepared, some bean meal is to be placed in the bottom of a crucible, above this nitre and tartar, then some auripigmentum, on this some of the copper plates with more auripigmentum over them: in this order of stratification we are to proceed till the vessel is full, and then to invert into the mouth another crucible having a hole in its bottom. A moderate heat is to be continued so long as any flame or fumes appear, after which the fire is to be raised so as to bring the matter into fusion, and continued in this state for an hour. It is not to be expected that this process can afford the ductile gold coloured metal which the author promises from it; for orpiment, in virtue of the arsenic of which it largely partakes, tinges copper, not yellow, but white. As Vigani throws a veil over some of his preparations, though commonly but a thin one, I have been led to suspect that he has done so here; and that by *auripigmentum* he does not mean the orpiment which makes a gold pigment for the painter, but zinc the auripigment for copper. If this explication be right, a yellow metal may doubtless be obtained, though the troublesome method of procedure is not to be recommended. The burning of sulphur upon the copper, and the repeated extinction of zinc in vinegar, do not appear to be of any advantage; and the gradual augmentation of the fire occasions always, as already observed, a great dissipation of the zinc.

It has been supposed by many, that the yellowness, resulting from mixtures of zinc and copper, was no other than a dilution of the coppery red by the whiteness of the zinc: if this was the case, silver would have a like effect, but silver is not found to give any yellowness to copper. The yellow colour produced from the combination of copper and zinc, is apparently a new quality; as much as the brittleness produced from the combination of two malleable metals, gold and tin. It has not been observed that any metal, besides zinc, yields any considerable yellowness with copper, though tin, in certain proportions, yields a slight one; or that any metal besides copper forms a yellow compound with zinc.

Silver is tarnished superficially, by certain vapours, as that of putrefied urine, to a colour so like that of gold, that abuses are said to have been often practised on this foundation, particularly in regard to wire and laces: Savary gives an account of several edicts issued in France for preventing these frauds. It is observable also that fine silver, on being melted with nitre, acquires frequently a yellow spot on the surface where the salt lay in contact with it; and Stahl affirms that silver, by being treated in a certain manner, with certain substances, of which nitre is the principal, may be tinged throughout of a golden colour: he conceals the process, for fear of giving occasion to imposition; though of this there does not appear to be much danger, for he observes that the silver acquires none of the other distinguishing characters of gold, and that the adventitious colour is very readily destroyed.

## II. *Gold coloured pigments.*

IN the gilding of wood, some pigments, approaching as near as may be to the colour of gold itself, are both laid  
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under the gold, and used also for the colouring of depressed parts where gold leaf cannot be conveniently applied. The substance chiefly employed for this purpose is yellow ochre; the colour of which may be improved, or brought nearer to the gold teint, by a small addition of vermilion or other red powders.

Of the mineral called auripigmentum or orpiment, some sorts are of a beautiful glittering gold colour. This mineral consists of arsenic and sulphur, and on being ground with oil for painting, yields an offensive smell, as sulphur always does when united with oils: this is the principal inconvenience it is accompanied with, and renders its use less frequent than it would otherwise be. Though it is offensive from the sulphur, the suspicion of its being poisonous in virtue of the arsenic appears to be without foundation, for the fetid vapour proceeds wholly from the sulphur, and even arsenic in substance, if we may judge from trials made on brutes, has its poisonous quality sheathed or destroyed by the combination of sulphur with it.

A beautiful gold coloured preparation, called *aurum mosaicum* or *musivum*, is obtained from tin. Some fine tin is melted in an iron ladle; and half its quantity of pure quicksilver, previously heated in another ladle till it begins to smoke, is poured into the melted metal, and the mixture stirred with an iron rod: when cold, the matter is found friable, and being reduced into fine powder, it is well mixed with half or a third its weight of sal ammoniac and the same quantity of flowers of sulphur. With regard to the proportion of these ingredients, practical writers differ not a little, and indeed they admit of great latitude, for I have succeeded equally with very different proportions: very little of any of them is retained by the tin in the subsequent part of the operation. The powder is put into a matras, or round glass with a short neck, which is placed in



a sand-bath, and the fire increased by degrees, so as to keep the sand at last red hot for some time. The fire being then suffered to decay, and the vessel broken when cold, a saline matter, consisting chiefly of sal ammoniac, is found in its upper part: under this is a dark red mass, which proves to be cinnabar, or a combination of mercury and sulphur: at the bottom is the aurum mosaicum, a sparkling, gold coloured, flaky mass, weighing about a twelfth part more than the tin employed.

The gold coloured talcs, formerly mentioned, have too much flexibility and elasticity to be reduced into powder of sufficient fineness for the purposes of painting: but there is one imitation of gold, for which powders of much fineness are not required, and for which the talcs are better adapted than any other material I know of, on account of their resistance to fire. A kind of glass, with gold coloured spangles diffused through its substance, has been much admired, and the preparation of it kept a secret: this appearance may be communicated by the yellow talcs, by mixing them well with powdered glass and bringing the mixture into fusion.

### III. *Gold coloured varnish or lacker.*

SILVER, coated with a transparent gold coloured varnish, is made to resemble gold so exactly, as wholly to supply the place of gold in some of the works called gilt. The basis of the varnish, or what gives adhesiveness and glossiness to the colouring matter, is a solution of lac made in spirit of wine.

Lac or lacca is a substance collected by certain insects in the East Indies: it is found incrustated on sticks or branches of trees, in brittle masses of a dark red colour, which being reduced into small grains, and freed from part of the colouring matter by infusion in water, are sold under the name of seed lac. It is in this state that the lac

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is to be used for varnishes: what is called shell lac, or the grains formed into plates by melting them in boiling water, does not answer so well.

The spirit must be highly rectified, or freed as much as possible from any admixture of phlegm or water, for otherwise it will not dissolve the lac. The most convenient and expeditious way, of preparing the spirit for this intention, is by adding some dry potash or other fixt alkaline salt: the salt imbibes, and dissolves in, the watery part of the spirit, and forms therewith a distinct fluid at the bottom, from which the spirituous part on the top may be poured off. More or less of the salt will be required according as the spirit is more or less phlegmatic: if the first quantity, after standing for some hours and occasionally shaking the vessel, wholly dissolves, more must be added and the agitation renewed.

The spirit being thus dephlegmed, some seed lac, reduced into fine powder, is added to it, in the proportion of about three ounces to a pint: the vessel being set in a moderate warmth for twenty-four hours and frequently shaken, a part of the lac dissolves; and the spirit, now tinged of a reddish brown colour, is strained off from the undissolved part, and set by for a day or two to settle. The digestion should be performed in a wide mouthed vessel, covered so as to prevent the exhalation of the spirit: the undissolved lac softens into a viscous mass, so as scarce to be got out through a narrow aperture.

In different portions of the foregoing solution, poured off clear after the straining and settling, some gamboge and annotto are dissolved separately. Gamboge is a yellow juice, issuing from certain trees in the East Indies, and exsiccated into masses by the sun's heat: Annotto is artificially prepared from the red skins of the seeds of an American tree, by steeping and agitating the seeds with water  
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till their colouring matter is transferred into the liquor: on boiling the strained liquor, the colouring matter is said to be thrown up to the surface in form of scum, which is afterwards exsiccated by itself, and formed into masses, which, as brought to us, are moderately hard and dry, of a brown colour on the outside, and a dull red within. Both these substances dissolve very readily in the spirit: the gamboge communicates a high yellow colour, and the annotto a deep reddish yellow. The solution of the gamboge is mixed with about half its quantity of that of the annotto, and trial made of the mixture on some silver leaf: if the colour inclines too much to the yellow or the red, more of the one or the other liquor is added, till the true golden colour is obtained. There are sundry other materials, from a due mixture of which a like colour may be produced, as turmeric, saffron, dragons-blood, &c.

The silver leaf being fixed on the subject, in the same manner as gold leaf, by the interposition of proper glutinous matters; the varnish is spread upon the piece with a brush or pencil. The first coat being dry, the piece is again and again washed over with the varnish till the colour appears sufficiently deep.

What is called gilt leather, and many picture frames, have no other than this counterfeit gilding. Washing them with a little rectified spirit of wine affords a proof of this; the spirit dissolving the varnish, and leaving the silver leaf of its own whiteness.

For plain frames, thick tin foil may be used instead of silver. The tin leaf, fixed on the piece with glue, is to be burnished, then polished with emery and a fine linen cloth, and afterwards with putty applied in the same manner: being then lackered over with the varnish five or six times, it looks very nearly like burnished gold.

The same varnish, made with a less proportion of the colouring materials, is applied also on works of brass; both

for heightening the colour of the metal to a resemblance with that of gold, and for preserving it from being tarnished or corroded by the air.

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## Addition to the HISTORY of GOLD.

**S**INCE the foregoing sheets went to the press, a new manufacture has been set on foot in London, for embellishing linen with flowers and other ornaments of gold leaf. The linen looks whiter than most of the printed linens; the gold is extremely beautiful, and is said to bear washing well. I have seen a piece, which I was credibly informed had been washed three or four times, with only the same precautions as are used for the finer printed linens, and on which the gold continued entire and of great beauty.

**T**HE Venetians have carried on a large trade, to the Levant, in a kind of brocade called *damaſquète*, which, though it has only about half the quantity of gold or silver as that made among us, looks far more beautiful. The flatted wire is neither wound close together on the silk threads, nor the threads struck close in the weaving; yet, by passing the stuff betwixt rolls, the disposition and management of which is kept a secret, the tissue or flower is made to appear one entire brilliant plate of gold or silver. The French ministry, ever vigilant for the advancement of arts and commerce, judged this manufacture important enough to deserve their attention; and accordingly, for contriving the machinery, they engaged the ingenious M. Vaucanson, known throughout Europe  
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for his curious pieces of mechanism, who, in the memoirs of the academy for the year 1757, lately printed, gives an account of his success, and of the establishment of such a manufacture at Lyons.

The lower roll is made of wood, thirty-two inches in length and fourteen in diameter; the upper one of copper, thirty-six inches long and eight in diameter: this last is hollow, and open at one end, for introducing iron heaters. For making the rolls cylindrical, he has a particular kind of lathe, wherein the cutting tool, which the most dextrous hand could not guide in a straight line through such a length as thirty-six inches, is made to slide, by means of a screw, on two large steel rulers, perfectly straight, and capable of being moved at pleasure, nearer, and always exactly parallel, to the axis of the roll.

He first disposed the rolls nearly as in the common flattening mill. In this disposition, ten men were scarcely sufficient for turning them with force enough to duly extend the gilding; and the collars, in which the axes of the rolls turned at each end, wore or galled so fast, that the pressure continually diminished, inasmuch that a piece of stuff of ten ells had the gilding sensibly less extended on the last part than on the first. He endeavoured to obviate this inconvenience by screwing the rolls closer and closer in proportion as the stuff passed through, or as the wearing of the collars occasioned more play between them; but this method produced an imperfection in the stuff, every turn of the screw making a sensible bar across it. To lessen the attrition, each end of the axes, instead of a collar, was made to turn between three iron cylinders called friction-wheels: but even this did not answer fully, for now another source of unequal pressure was discovered. The wooden roll, being compressible, had its diameter sensibly diminished: it likewise lost its round-

ness, so that the pressure varied in different points of its revolution. On trying different kinds both of European and Indian woods, all the hard ones split, the soft ones warped without splitting, and, of more than twenty rolls, there was not one which continued round for twenty-four hours even without being worked in the machine.

These failures put him upon contriving another method of pressing the rolls together, so that the force should always accommodate itself to whatever inequalities might happen. The axis of the copper roll being made to turn between friction wheels as before, that of the wooden one is pressed upwards by a lever at each end furnished with a half collar for receiving the end of the axis. Each lever has the end of its short arm supported on the frame of the machine, and the long arm is drawn upwards by an iron rod communicating with the end of the short arm of another lever placed horizontally: to the long arm of this last lever is hung a weight, and the levers are so proportioned, that a weight of thirty pounds presses the rolls together with a force equivalent to 17536 pounds, which was found to be the proper force for the sufficient extension of the gilding. By this contrivance four men can turn the rolls with more ease than ten can turn those which are kept together by screws; and the same weight acting uniformly in every part, the pressure continues always equal, though the wooden roll should even become oval, and though the stuff be of unequal thickness.

A piece of cloth, of about two ells, is sowed to the beginning and end of the stuff, to keep it out to its width when it enters and parts from the rolls, which could not be done by the hands for fear of burning or bruising them: as it would take too much time to sow these cloths to every small piece of an ell or two, a number of these is sowed together. The stuff is rolled upon a cylinder, which

is placed behind the machine, and its axis pressed down by springs to keep the stuff tight as it comes off. Four iron bars, made red hot, are introduced into the copper roll, which in half an hour acquires the proper degree of heat, or nearly such a one as is used for the ironing of linen: the wooden roll is then laid in its place, and the machine set to work. If more than thirty ells are to be passed at once, the wooden roll must be changed for another, for it will not bear a longer continuance of the heat without danger of splitting, and therefore the manufacturer should be provided with several of these rolls, that when one is removed, another may be ready to supply its room: as soon as taken off from the machine, it should be wrapt in a cloth and laid in a moist place.

The principal inconvenience, attending the use of this machine, is, that the heat necessary for extending the gilding, though it improves the brightness of white and yellow silks, is injurious to some colours, as crimson and green. A double pressure will not supply the place of heat; and the only method of preventing this injury, or rendering it as slight as possible, appeared to be, to pass the stuff through with great celerity.

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### III. EXPERIMENTS

Of the conversion of GLASS VESSELS into PORCELAIN, and for establishing the principles of the art.

**H**AVING many years ago distilled some wood foot, with a strong fire, in a green glass retort set in sand, I observed great part of the bottom of the retort, after the operation, to be remarkably changed : it was quite opaque, of a black colour on the inside where the foot had been in contact with it, and whitish on the outside where it rested upon the sand : it had no longer the brittleness of glass, but broke with difficulty like the better kinds of stone ware : its internal substance was white like porcelain ; and not of a glassy smoothness, but of a fine fibrous texture.

This singular change, in a body supposed so little susceptible of alteration, was attributed to the vapours of the foot having penetrated into the substance of the glass : sundry pieces of the same kind of glass were therefore intermixed with another quantity of foot, in an iron pot, to which was adapted a head with a receiver, and the distillation conducted in the usual manner, till nothing more could be forced out from the foot in a strong fire : on examining the pieces of glass, some, in the middle of the matter, seemed scarcely at all altered ; others, about the sides and bottom of the pot, were changed in part nearly in the same manner as the bottom of the retort had been.



This change of glafs has doubtlefs happened often, without being attended to. Neumann is the firft writer by whom I find it taken notice of: in diftilling milk in a glafs retort, he obferved that the bottom of the vefſel acquired the appearance of porcelain, which he attributes to the fine white earthy matter of the milk forced into the glafs by the heat.

M. de Reaumur was led to the ſame diſcovery by analogical reaſoning, as I have already mentioned in the notes on Neumann's chemical works, where a further account of this affair is promiſed. Reaumur, having had large experience of the effects of inflammable and earthy bodies on iron, by baking, in the converſion of forged iron into ſteel, and in the ſoftening of caſt iron, applied the ſame proceſs to common glafs, and thus diſcovered the new porcelain, which he calls porcelain by tranſmutation, porcelain by revivification, or porcelain of glafs. The glafs was cemented, or baked, in crucibles, firſt with the ſoot, powdered charcoal, and other ſubſtances employed in the experiments on iron: it became opaque, externally dark-coloured or black, but internally of a fine white colour. Other materials were then made trial of, in hopes that ſome one might be found, which ſhould occaſion the ſurface to be as white as the internal part: among the ſubſtances tried in this view, of which he gives no particular account, he judged white ſand and plaſter-of-paris, or rather a mixture of the two, to anſwer the beſt. He directs veſſels of common green glafs to be filled and ſurrounded with this mixture, in large crucibles or cementing pots, ſuch as are commonly uſed for the baking of earthen wares; the crucibles to be covered and luted, and ſet in a potter's furnace: the ſame fire, which bakes the common wares, changes the glafs veſſels into veſſels of the new porcelain. He obſerves, that this porcelain may  
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be made at a very cheap rate, as the glass maker can form vessels more expeditiously than the potter, and as it is happily the very coarsest green glass that yields the finest porcelain: That it is easily distinguished from all the other sorts of porcelain by the texture which it exhibits on breaking, as it has nothing of the granulated appearance of the other porcelains and earthen wares, any more than the glossy smoothness of glass and enamels, the surface of the fracture being composed of fine fibres like silken threads: That in beauty it is inferior to the Chinese, but equal to many sorts that are held in esteem; that in utility, and every essential quality of porcelain, it is equal to the best, and that in some respects it is superior to all that have hitherto been made: That it suffers no injury from being suddenly heated or cooled, bears a vehement fire without melting or altering its figure, and hence, besides its use for ornamental vases, promises to make excellent vessels for the chemist.

The character given of this porcelain by Reaumur, and the valuable qualities he ascribes to it, rendered it an object of more importance than it had appeared at first, and engaged me in a further examination of it. That the enquiry might be carried on with some regularity, it was divided into five heads. (1.) To trace the gradual progress of the change from the state of glass to that of perfect porcelain, and to discover whether a continuance of the process would be productive of any further changes. (2.) To determine the qualities of this kind of porcelain, and how it differs from other porcelains and from glass, in those properties which regard the application of it to common uses. (3.) To compare the effects of different cementing materials on the same glass, and (4.) the effects of the same materials on different kinds of glass. (5.) To ascertain, as far as might be, the cause of the change, or the

the true principle on which it happens. The following is the general result of the experiments I have hitherto made upon these subjects.

## S E C T. I.

*Experiments of the successive changes produced in Green-Glass by baking.*

**I**N order to determine the progress of the visible change produced in glass by baking, and the effects of different degrees or a different continuance of the heat; a number of pieces of common quart bottles were surrounded with white sand, in crucibles, which were placed in a wind-furnace, built on purpose for experiments of this kind, consisting of several chambers one over another, with proper apertures in the middle for the ascent of the flame and heated air through each. The crucibles were left open, that some of the pieces might be taken out from time to time, for discovering how the change went on: and that the effects of the process might be seen in its full extent, the fire was slowly raised, and continued for upwards of forty hours.

Such pieces as were taken out before they became red hot, did not appear to have suffered any change, though they had been kept for several hours in a heat very little below ignition. In a low red heat, the change did indeed take place, but exceeding slowly; those which had been exposed for several hours to such a heat being very little altered. In a strong red heat, approaching to whiteness, just not sufficient to make the glass melt, the change went on pretty fast: after an hour's continuance of this degree of heat, the glass had acquired the appearance of porcelain to a considerable thickness; and in two hours longer, the thickest pieces, of the

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bottoms

bottoms of the bottles, were found fully changed throughout. In those pieces which were slowly affected by a weak heat, and those which were more hastily acted upon by a moderately strong one, the progress of the change itself was, for the most part, nearly in the same manner.

The green glass became first of a bluish colour on the surface, and in this state, when held between the eye and the light, it appeared less transparent than before, and of a yellowish hue. After this it was found changed a little way on both sides into a white substance, externally still bluish; and as this change advanced further and further within the glass, the vitreous part in the middle approached more and more to yellow: the white coat was of a fine fibrous texture, and the fibres disposed, nearly parallel to one another, not longitudinally as might be expected from the direction given to the parts of the glass in blowing it into vessels, but crosswise to the thickness of the piece. By degrees, the glass became throughout white and fibrous, the external bluishness at the same time going off, and being succeeded by a dull whitish or dun colour: the fibres were for the most part regularly and uninterruptedly arranged from each side to the middle, where the fibres from the two sides, meeting together, formed a kind of partition: along this juncture, there were in some pieces considerable cavities here and there; others were perfectly solid.

The pieces which were continued in the fire for any considerable time beyond this period, and those which were afterwards returned to it along with fresh sand, suffered a fresh change, which proceeded, like the first, from the surface to the center. The fibres became divided or cut into grains at the outer ends, and by degrees they were thus successively divided through their whole length; the whole internal part of the porcelain assuming a granulated

mulated texture, not ill resembling that of the common porcelains.

Those which were longer and longer exposed to the fire, received more and more alterations. The grains, at first fine and of some degree of glossiness, grew larger and duller; and at length, through sundry gradations, less remarkable and less uniform, what had once been glass, and afterwards a compact hard porcelain, became a porous friable substance, like a mass of white sand slightly cohering.

During the change of the glass into a fibrous porcelain, it generally preserved the smoothness of its surface, and the sand freely parted from it: in the subsequent changes, part of the sand baked together upon the surface, and strongly adhered, not to be got off, and not greatly differing from it in appearance; I have sometimes been at a loss to distinguish the matter which had been glass from the sand that surrounded it. In some pieces the sandy coat was parted from the internal matter by a number of fine cavities resembling a dotted line: in others, they were closely applied together.

Such were the general effects of continued cementation in many repetitions of the experiment, though not without variations in some particulars. Sundry pieces became throughout white, and almost opaque, and some blue, before they contracted any fibrous coat, which afterwards proceeded in the same manner as in the others. Some pieces, being broken in different parts after they had been changed to a fibrous state, instead of the uniform transverse disposition of the fibres, had several prominences on the surfaces of the fractures, from which the fibres issued as rays in all directions. After the fine granulated state, which succeeded to the fibrous on a continuance of the cementation, some pieces became porous, while in others the

grains formed a kind of close plates, and the mass proved very compact. In some, the texture was close and even throughout, without any distinguishable grains, fibres, or plates. Of some of these variations, the probable causes will appear in the following section: others depended perhaps upon the nature of the glass employed.

Notwithstanding these, and other lesser differences, the general appearances, and the gradation of the visible change proportionably to the degree of baking, are so strongly marked, that, from the texture of the porcelain on breaking, we can always judge with certainty of its quality, or of the degree to which it has been baked. Reaumur has also taken notice of something of this kind, finding the porcelain sometimes turn out granulated instead of fibrous: but his experiments do not seem to have been carried far enough to discover the foundation of this difference; to discover, that the different kinds of texture regularly succeed one another from the continued action of one cause, that they are all at the command of the workman, and that they are accompanied with remarkable differences in the intrinsic qualities of the porcelain.

## S E C T. II.

*Experiments of the quality of the substance into which Green Glass is converted by baking.*

**T**HE porcelain into which glass is converted by baking, whatever its superficial colour be, is, in its internal substance, always white; and its whiteness is frequently not inferior to that of the internal part of China ware. Its surface is unhappily the part which is least beautiful. All the thick pieces were quite opaque: several thin ones had a degree of transparency, resembling that of China ware. In this respect considerable differences appeared: a very thin

thin coat of fibrous or granulated porcelain upon the glass gave opacity; of the pieces of a close smooth texture, some, tho' pretty thick, were semitransparent, and others, tho' thinner, were opaque.

In the fibrous state of the porcelain, it is considerably hard; much more so than the glass it was made from, and than any of the common kinds of porcelain. It freely and plentifully strikes fire with steel, which green glass does but in a low degree. It cuts common glass, as indeed one piece of glass in some measure will another; but neither any of the common kinds of glass, nor the file which cuts them, make any mark on the fibrous porcelain. Even when the change is scarcely visible on the surface of the glass, the external part is found sensibly harder to the file than the internal.

It perfectly resists both acid and alkaline liquors, neither permitting them to transude through it, nor being at all corroded by them.

It bears vicissitudes of considerable degrees of heat and cold, so that vessels of it may be plunged at once, without any danger of their cracking, from freezing into boiling water. It may likewise be set on burning coals, with much less precaution than any of the porcelains or earthen wares used for containing liquids.

In a moderate white heat, it melts, so as to be easily drawn out into long slender strings, which appear semitransparent, and, on breaking, prove not fibrous as before, but of a vitreous smoothness like white enamel. Some of the melted pieces were considerably bright or glossy, some had no glossiness, and all of them proved softer than before the fusion, seeming, though very compact, to be little harder than common green glass.

It does not however melt near so easily as the glass itself. When the cementation has been continued no longer than

till only the external part of the glass was changed, I have often observed, that on hastily raising the fire, the unchanged glass has melted and run out, leaving a cavity in the middle with a crust of porcelain on each side.

When the porcelain has been so far baked, that the fibrous texture has disappeared, and a coarse granulated one come in its place, it proves far softer than before: it now neither strikes fire with steel, nor cuts glass; but is itself cut with ease both by common glass and by the file.

With this imperfection, it acquires an advantage of greater resistance to fire: the longer the cementation was continued, the fusibility seemed always to be more and more diminished. A piece of the concave bottom of a common green bottle, which had its fibres only in part changed into grains, stood the melting of a lump of brass, of about two ounces, without anywise altering its figure, or suffering any other apparent change, than that the thin edges were rounded off, and covered in some parts with a green glazing, which seemed to have exuded from the mass. Some pieces of the same cemented glass being put into a small crucible, into which another was inverted and closely luted, and the whole urged for two hours or more in a sea-coal fire vehemently excited by bellows, the pieces melted together into a very spongy mass, of an almost pearly whiteness and some brightness, intermixed in different parts with a green glass, exactly resembling the glass employed, and which probably was no other than a part of it, that had escaped unchanged in the cementation, though not distinguishable by the eye, till thus spued out from the less fusible porcelain, and collected in its cavities. Pieces which had acquired throughout a fine bright grain, were likewise in an intense fire, made to melt or soften into lumps, which generally proved spongy:



spongy: but those, in which a large coarse grain had succeeded to the fine one, could scarcely be made to soften at all, whether exposed to the fire in crucibles, or in contact with the burning fuel. These unfusible pieces, though a continuance of the baking with a moderate heat would have rendered them more and more porous and friable, on being hastily urged with an intense fire became remarkably more compact than they were before; some of them seemed superiour in solidity to any kind of ware I know of.

It may hence be presumed that the smooth texture observed in several pieces after the baking, so close and compact that neither grains nor fibres can be distinguished, proceeds from their having undergone a greater degree of fire than the others. Several of the pieces, which acquired this appearance in the baking, had in part begun to melt, and others had not: perhaps the former received their compactness from an augmentation of the heat, in the earlier period of the cementation, and the latter in the subsequent stages when their fusibility had been greatly diminished; and probably the semitransparency of some of the compact pieces, and the perfect opacity of others, proceeded from the same cause. It is plain that the resistance to fire, which Reaumur makes a general property of this kind of porcelain, belongs to it only in certain states; and that the vessels, which he found to bear the vehement heat of a forge, could not be of the fibrous porcelain he describes, but such as had been baked considerably beyond that period.

From the foregoing general results of a great number of experiments, a particular detail of which could add little either to the instruction or entertainment of the reader, it follows, that this porcelain, though little adapted for ornamental purposes, on account of its want of beauty

on the outside, is very well fitted for many kinds of useful vessels.

Green glass mortars, or planes for levigation, may be advantageously changed into this hard porcelain, greatly exceeding the hardness of any kind of marble, and no ill substitute for agate or porphyry. Mortars and levigating planes of this kind seem for some purposes particularly excellent, as for the grinding of enamels, which, though they should wear off some of the matter of the baked glass, as well as of marble or alabaster, yet cannot be so much injured by the little they receive from the former, which is analogous to their own composition, as by the greater quantity they receive from the latter, which is of very different quality.

Glass vessels, intended for bearing the fire, may, by converting them into porcelain, be made capable of bearing it in a much greater degree, and rendered much less liable to crack. As vessels of this porcelain have in these intentions manifest advantages above glass, they have advantages also above all the other porcelains and earthen wares. The unglazed earthen wares permit saline liquors to soak through them; those which are glazed have their glazing corroded by acids; the compact stone wares, and those in general which have clay in their composition, as all the common wares necessarily have, are corroded and partly dissolved by certain acids in a boiling state, particularly by the vitriolic: while the porcelain from glass is neither affected by these causes, nor so liable to be injured by hastily exposing it to the fire. I know of no material, so proper, and so commodious, for evaporating vessels, or others, that shall be proof against all kinds of saline liquors.

There are some vessels also, which may be figured more perfectly, and with less expence, in this kind of  
porcelain

porcelain than in any other. Long-necked matraffes for instance could scarcely at all be formed by the potter, of that equal thickness, and internal smoothness, to which they are expeditiously blown by the glass-maker.

The above account of the qualities of this porcelain in its different states, points out a caution to be observed in the process, especially where mortars are to be changed, or in other cases where great hardness is required; viz. to discontinue the baking at the period of the greatest hardness; for otherwise the matter soon becomes soft again, and even softer than the glass was at first. It seems to have acquired its full hardness as soon as it has become white and fibrous; and hence perhaps it may for most purposes be adviseable to discontinue the operation as soon as the glass appears covered with a moderately thick white coat. Fragments of the same kind of glass, put in along with the vessel to be changed, and occasionally taken out and broken, will serve to inform the operator how the change goes on. Of wide-mouthed vessels, several may be placed within one another, with sand between them. In all cases, care must be taken to apply the heat, as equally as may be, all over the crucible or pot containing the vessels, that the change may be as uniform as possible throughout: no particular contrivances however are necessary for this use, the same caution and the same furnace, employed for baking the common fine wares, being sufficient for the baking of glass.

### S E C T. III.

*Experiments of comparing the effects of different kinds of materials on Green Glass by baking.*

**P**IECES of green glass bottles were surrounded with powdered charcoal, foot, and sundry kinds of earthy bodies, in separate crucibles, which were all covered and

luted, and placed in a wind-furnace : the fire was gradually raised, so as to make the crucibles of a moderately strong red heat, and continued in this state for six or seven hours. The fire being then suffered to decay, and the crucibles taken out and examined, the glass was found in all to have become porcelain. In the upper chamber, most remote from the action of the fire, the pieces were in general fibrous, and some of the thick ones not changed throughout : in the lower chamber, more immediately exposed to the fire, where the matters intermixt with the glass were the same as in the upper one, the fibres had in most of the pieces disappeared, and given place to grains. There did not seem to be any differences, that could be ascribed to the quality of the cementing matters, in the internal colour, hardness, texture, or the regular succession of the changes ; though, in external appearance, the differences were very considerable.

All the pieces, which had been surrounded with foot, with charcoal, or with mixtures of the two, were externally of a deep black colour : where small proportions of foot or charcoal were mixed with white earths, the porcelain turned out of a brown colour, deeper or lighter, according as the inflammable ingredient was in greater or less quantity. Judging that the dark colour, which the foot or charcoal communicate, might be burnt off by fire assisted by the action of the air, I put some of the black pieces into a crucible, which was placed open in a blast furnace, and excited the fire, for above an hour, to as great a degree as the porcelain seemed capable of bearing without beginning to melt : the colour resisted this heat, continuing as deep a black as at first.

The coloured clays, boles, ochres, powdered red bricks, and the sands which burn red, gave likewise different shades of brown, inclining more or less to blackish, red-

dish, or yellowish : these colours also resisted the joint action of fire and air, equally with the preceding. The browns and blacks were on some pieces very glossy and tolerably beautiful.

Different white earths gave different shades of whitish, greyish, or brownish ; but none of them gave a pure white, nor a whiteness equal to that of the internal part of the porcelain. It is difficult to distinguish precisely the effect of particular earths, in this respect, from that of the degree of fire or other circumstances in the process : for of pieces of the same bottle, which had been surrounded and baked with the the same earth, some turned out manifestly whiter than others. White sand, calcined flint, and gypsum, seemed in general to give the greatest whiteness, and tobacco-pipe clay the greatest brightness or glossiness, though this last, baking together in a lump upon the porcelain, made the surface in some parts rough.

In this experiment, and in several repetitions of it, the surface of some of the pieces proved rough like shagreen, that of some wrinkled like shrivelled leather, and of others blistered or full of blebs. These appearances seem to have depended more upon the fire having been too strong or too hastily raised, so as to make the glass soft or ready to melt, than on any particular quality of the materials with which it was surrounded ; though it appeared also that some materials dispose to these imperfections more than others. Pieces of one and the same glass bottle having been baked, some with tobacco-pipe clay, and others with quicklime, and with bone ashes, in the same degree of fire, and for the same length of time, the porcelain with the clay proved almost every where smooth and polished as the glass was at first, while those with the lime and with the bone ash were all over wrinkled.

From the different effects of different materials on the surface of the porcelain, I have endeavoured to add some embellishment to this kind of ware. By covering the outside of the glass vessel to be changed with powdered charcoal, or with a mixture of powdered charcoal and white sand, and the inside with white sand alone, the porcelain vessel, resulting from the cementation, has proved of a deep black or a bright brown colour without, and of a tolerable whiteness within. By covering different parts of the glass with different powders, as charcoal, white sand, white clay, lime, and coloured earths, I have obtained, in one piece, variegations, not inelegant, of different shades of black, brown, grey and whitish, and with glossy and wrinkled veins. The above colours, with the bluish cast which the glass exhibits before the change is completed, are all that I have observed glass to receive by the process of baking.

As the action of foot and charcoal on iron, in the conversion of iron into steel by baking, is promoted, and in some respects varied, by the admixture of a little sea salt, and of the saline ashes of wood, I made trial of the same composition for the baking of glass; and as the inflammable ingredients in this mixture could not fail to give a black colour to the porcelain, I tried at the same time, in another crucible, wood ashes alone, which had been calcined in a strong fire, to burn out all remains of their inflammable matter, and reduce them to perfect whiteness.

The steel-making mixture did not answer so well as the foot or charcoal by themselves: the glass did indeed become porcelain, but of a bad quality, all over blistered, with many cavities, and some of them very large, in the internal part. The wood ashes, instead of changing the  
glass

glafs into porcelain, melted and united with it into one femivitreous lump.

I tried likewise colcothar, or the red calx of iron, which remains from vitriol after the acid has been expelled by fire. Pieces of green glafs being furrounded with this powder, and baked for feveral hours in the upper chamber of the wind-furnace, the glafs and colcothar were all found to have run together into a black mafs, externally rough, internally fomewhat fmoother and cavernulous, of confiderable hardnefs fo as to ftrike fire freely with fteel. It is pretty remarkable, that a metallic fubftance fo refractory in the fire, fhould be fo greatly difpofed to melt with green glafs.

#### S E C T. IV.

*Experiments of the baking of different forts of Glafs, and of bodies approaching to a vitreous nature.*

**G**LASS confifts of earthy or ftony fubftances, or metallic calces, brought into fufion and tranfparency in a ftrong fire. Pure unmixed earths cannot be made to vitrefy by any known degree of fire; but frequently one kind of earth is made vitrefcible by mixing with it a certain proportion of a different one, which feparately is as unfufible as the other: thus clay and chalk, though each by itfelf is altogether unfufible, yet when mixed together in due proportions, melt and form a truly vitreous compound: in feveral of the experiments I have been giving an account of, the crucibles were found partly vitrefied, not on the outside which had been immediately expofed to the fire, but on the infide, which had been in contact with earths of a different kind from thofe of which the crucible was compofed. The feveral forts of glafs in common ufe are prepared however on another principle;

principle; from sand, calcined flint, or pebbles, mixed with certain metallic or saline bodies, by which the earth is brought into fusion more easily than by the addition of other earths.

Some glasses of each of these kinds were cemented in the same manner as the green glass bottles in the preceding experiments; in hopes, that by pursuing the effects of the process upon a variety of bodies, though nothing should result of practical utility, the nature of the change, philosophically considered, might at least be illustrated.

*I. Vitreous bodies composed of earths, without metallic or saline additions.*

PIECES of crucibles, which from vehemence of fire had melted into a semitransparent glassy state, were surrounded with bone ash; which was here made choice of as being the most indisposed to vitrefy of all the earthy bodies I know of. As this kind of glassy matter is very hard of fusion, the crucible containing it was placed in a blast furnace, and the fire strongly excited by the bellows for several hours, that the matter might undergo as great a degree of heat as it could bear without melting: the fuel was sea-coal, coaked or charred as for the drying of malt, which I find to be a very convenient fuel where bellows is used, being very durable, and giving a strong heat, without smoke. The crucible being grown cold, the pieces were found of their original vitreous appearance, and without any change in their colour or transparency. Nor have I observed that any compositions of mere earths, whether brought to a perfectly vitreous or only to a semivitreous state, received any alteration from this process. China ware, which is reckoned a mixture of two different earths semivitrified, was also found to resist it: the glazing  
of



of the ware softened, so as that the powder it was surrounded with partly adhered, but in other respects there was no sensible alteration. I tried likewise some of the more simple transparent and semitransparent stones, as crystal and flint; which, by long cementations with different materials, received no other change than the diminution of hardness and transparency which simple heat produces in them.

## II. *Metallic Glasses.*

PURE glass of lead, surrounded with sand, and baked for many hours in a moderate red heat, suffered no perceptible alteration, except where some of it had melted off and dissolved a part of the sand. Common flint glass, in which the flint or sand that makes its basis is vitrified chiefly by an addition of calx of lead, proved also unsubduable by cementation: it became rough and brownish on the outside, and internally somewhat cloudy, but gained nothing of the appearance of porcelain by long continued and repeated bakings.

I cemented likewise some glasses tinged with metallic bodies, as the common blue glass tinged with the preparation of cobalt called zaffre, blue and green glasses with copper, and the ruby glass already mentioned in the tenth section of the history of gold. All of them retained their vitreous appearance, and suffered very little change even in their colour: the ruby glass grew somewhat darker, and one of the copper glasses more dull, but the blue glass with zaffre did not appear to have received any alteration. The bone ashes, with which all these glasses were surrounded, adhered to them pretty firmly, probably from the surface having been softened or partly melted by the heat: on the zaffre glass and the ruby glass, the earthy crust remained white as at first: on all the copper glasses

it was reddish ; on that particularly, which had lost considerably of its beauty in the process, the bone ash was tinged of a fine flesh colour. This glass had been prepared from twenty-four parts of green glass, four of borax, and one of the powder separated by agitation from an amalgam of copper.

### III. *Glasses prepared with saline additions.*

ALL the glasses that could be changed into porcelain were such as had been brought to their vitreous state by means of saline bodies ; though some of this class resisted the operation, and in those which did become porcelain, there were considerable differences, in regard both to the facility of the change, and the quality of the porcelain itself.

Green glass bottles, composed of sand and the saline ashes of wood, answered much the best ; and the French bottles better, in point of colour, than the English. One of our common quart bottles, and a French quart bottle, being surrounded with the same sand, and baked in the same fire, for the same length of time, the porcelain from the French bottle turned out, in several repetitions of the experiment, manifestly the whitest, tho' in other respects no material difference was observed. It is probable that the difference in colour proceeded from the French glass being made with a whiter sand than the English : it is said that the sand used for green glass in France retains its whiteness, in great measure, after strong calcination ; while that of our glass-houses burns reddish.

The vials, in which Hungary water is brought from France, are very difficultly converted into porcelain, and the porcelain they afford is less white and less compact than that of the common bottles. The vials are much more fusible than the bottles, probably from their having a  
larger

larger admixture of saline matter: they begin to melt nearly as soon as the fire is raised high enough to change them; and how carefully soever the process is managed, a part of the inside commonly runs out, and the sand they are surrounded with bakes into a hard crust upon the surface. The lower portion of one of these vials having been cemented with a mixture of sand and gypsum, a part of it appeared changed throughout into a pretty hard porcelain, a part into a substance resembling the mixture baked together, and a part seemed scarcely changed at all: there were many large cavities, and the glass, which had run out from them, coated a part of the mixture with a green glazing. In some other trials the change was more equal, but I have never obtained from these vials a porcelain so uniform, or so hard, as from the common bottles.

Glass tubes, of a pale green colour, were affected nearly in the same manner as the Hungary water vials: they seemed to be somewhat less disposed to melt, and the sand did not so strongly adhere to them: from whence it may be presumed, that this kind of glass has a larger proportion of saline matter than the common bottles, but less than the Hungary vials.

The common pale green glass retorts and receivers did not answer well. A piece cut off from the bottom of a retort, and several circular segments of receivers, were placed within one another in a large pot, with some bone ash between and surrounding them, and cemented in a wind-furnace for several hours. They all became brownish, rough and shrivelled on the surface, in some parts blistered, and in some extremely thin as if part of the glass had melted off. They were semitransparent, nearly in the same degree as the finer sorts of stone ware. They easily broke, and appeared internally white, not fibrous or granulated, but of a smooth glassy surface.

Common window glafs appeared to fuffer the fame change as the glafs bottles, becoming opaque, and internally both fibrous and granulated according to the continuance of the fire : but it was greatly difpofed to blifter, and part of the glafs generally melted out.

The finer fort of glafs called crown glafs, and looking-glafs plates, did not become porcelain at all. In a moderate heat they grew wrinkled and shrivelled on the furface, and lefs transparent than before, but ftill remained glafs : on repeating the cementation with a ftronger heat, they partly melted and mixed with the furrouring powder, but did not appear to have fuffered any other alteration. A glafs which I had prepared myfelf from calcined flint and pure fixt alkaline falt, remained alfo unchanged, in the fame heat, and furrourded with the fame powders, by which common green bottles had been turned into perfect porcelain. Green glafs itfelf, melted with an additional quantity of falt, amounting to about a ninth part of its weight, and then cemented with fand, continued like-wife unchanged.

The foundation of thefe remarkable differences may be prefumed, from this laft experiment, to depend chiefly on the different quantities of falt in the feveral forts of glafs. The vitrification of fand with wood-afhes is influenced not a little by the action of the two earths on one another ; fo that, though vehement fire reduces the mixture into glafs, yet the quantity of faline matter in the afhes is much lefs than would be fufficient for the vitrification of the two earths feparately. In the other coarfe forts of glafs, a larger proportion of the afhes, and confequently of faline matter, is ufed, or fome alkaline falt itfelf is added, to render the mafs more fufible. In the fine glaffes, the quantity of falt is ftill larger, the vitrification being effected almoft wholly by this ingredient.

It

It seems to follow, from the whole, that bodies of the glassy kind are changeable into porcelain by baking, only in so far as their vitrescent state has been procured by means of saline substances; that those which hold the least salt are the most easily changed, and that the porcelain they afford is the most perfect; and that those, in which the proportion of salt is large, are very difficultly, if at all, made to undergo this change. Agreeably to these remarks, M. de Reaumur observes, that the very worst glass makes the best porcelain; and suggests, that in order to the perfection of this kind of ware, it may be necessary for the glass-maker to acquire a habit of blowing vessels from more refractory sorts of glass than those which are commonly worked. Perhaps the same end might be obtained more advantageously on another principle, which the foregoing observations point out, *viz.* by forming the glass of certain earthy compositions more disposed to vitresfy than those commonly employed; so that a very little salt shall be sufficient for their vitrification in the furnace of the glass-house, and that the glass they afford, instead of being more refractory, shall be even more fusible than the common green glass.

The different effects of cementation on different kinds of glass may perhaps afford some light into the cause of the change which coarse glass undergoes, and some useful characters and discriminations of different vitreous and semivitreous bodies.

## S E C T. V.

*Observations on the cause of the changes which green Glass undergoes by baking.*

**T**HE most obvious way of accounting for this extraordinary change is, to suppose the earthy or other unvitrescible particles of the matters, with which the

glass is baked, to be forced into its substance by the heat : such is the idea that first occurred to me on the discovery of this change, and such is the idea of Neumann and Reaumur. But specious as this theory appears to be, there are some facts which seem to overthrow it.

If the change proceeded from the introduction of any extraneous matter into the glass, the porcelain would weigh more than the glass ; as steel, prepared from forged iron by cementation, is found to weigh considerably more than the iron before the cementation. But pieces of glass bottles, baked with sand till they had become fibrous throughout, and then wiped clean from the sand, were found, on several trials, to have received no increase of weight.

In some of the foregoing experiments in which the glass became perfect porcelain, the cementing material was a very coarse sand, which had been sifted from the finer grains for other uses. Is it not improbable, that the large grains of sand should be subtilized by the heat, and driven every where so equally into the substance of the glass, as to produce the remarkable fineness, and regularity of texture, of the fibrous porcelain ? Charcoal, which gives so permanent a blackness to the outer surface, can scarcely be supposed, when introduced into the internal part, to make it white. Nor could the porcelains, produced with different materials, be so exactly alike in their internal substance, if they proceeded from a coalition of the different bodies with the glass.

When green glass is heated till ready to melt, and then suffered to cool, it frequently contracts bluish specks or veins ; which induced me to suspect, that the same change was there beginning, as happens at the beginning of the baking. In pursuance of this observation, I placed some necks of quart bottles upright in large crucibles,  
securing

securing the lower ends in a bed of luting : the crucibles being closely covered, and exposed to the same degrees of heat as in the preceding experiments, the glass underwent the same changes as if it had been surrounded with sand ; with only this difference, that the changes happened much more slowly ; and that the pieces of glass having no solid matter to support them at the sides, many of them, made soft by the heat, had failed and bent downwards. It seems manifest from this experiment, that the sand or other materials are of use only for expediting the process, and affording a support to the vessel ; and that they are entirely inessential to the porcelain itself.

There are other facts which seem to shew, that the glass, instead of receiving any new ingredient in its conversion, loses a part of one of its own, at least in the latter stages of the process. In the cementation with sand, the sand near the surface of the glass, as already observed in the preceding part of this essay, was commonly found to cake together ; a presumption that it had imbibed some of the saline matter of the glass, for sand of itself is never found to cohere by heat. When fresh pieces of glass were cemented repeatedly with the same sand, the sand actually began to melt, and covered the surface of the glass, or of the porcelain resulting from it, to a considerable thickness, with a semivitreous coat, which adhered so strongly as not to be separated by a blow. When the baking of one piece of glass was long continued, it became friable and porous, the adjacent sand concreting at the same time into a mass scarcely to be distinguished from it.

From these observations I apprehend it may be concluded, that a part of the alkaline salt of the glass exudes by the heat, and is imbibed by the surrounding matters ; and that by a long continuance of the baking, so much

of the alkali is forced out, that there is scarcely enough left to make the earthy basis of the glass cohere. Thus glass, whose production has been commonly supposed to be the utmost limits of the power of fire, has its earth and its salt, which one degree of fire had so firmly united, almost wholly disjoined by another.

If these principles be just, they afford a satisfactory explanation of the most remarkable phenomena of the process; as of those glasses only being convertible into porcelain which are prepared with saline matters, of those being easiest changed which have least salt, of the same changes being producible by cementation with very dissimilar materials, of the glass becoming less and less fusible in proportion to the change, of its becoming more and more hard to a certain point, and afterwards more and more brittle.

It has been observed above, that glass, in its conversion into a fibrous porcelain, did not receive any increase of its weight: it must be added also, that it scarcely suffered any sensible diminution. I do not however apprehend, that this experiment is altogether irreconcilable with those which seem to prove the exudation of the alkaline salt of the glass. The strong marks of the exudation do not appear till after the porcelain has considerably passed its fibrous state; and then the sand, concreting inseparably upon its surface, prevents our being able to determine any thing from the weight. Green glass has as small a proportion of salt, as can be made to vitrify the earthy matter in the strongest fires of the glass-house: it is probable therefore that the separation of a very minute portion of the salt may be sufficient for producing the first degree of change, or rendering the mixt no longer glass; the fusibility of the fibrous porcelain seems to be a proof, that the quantity of alkali separated at this



period cannot be considerable. Perhaps also this first degree of change may depend in part on an alteration produced, by the heat, in the glass itself considered as a compound, or in the nature of its alkaline ingredient. The remarkable differences, in point of brittleness, which happen to glass merely from the quick or slow manner in which it is cooled, are well known : and as to alkaline salts, when exposed for some time to a moderate fire, a part of them is always found to lose its saline nature, and become an earth.



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IV. Of the EXPANSION or CONTRACTION of certain BODIES at the Time of their passing from a fluid to a solid State.

**T**HE expansion of bodies by heat, and their contraction by cold, supposed to proceed always uniformly by equal augmentations or diminutions of heat, appear to have sundry irregularities; which may deserve to be taken notice of, not only in a philosophical view, but likewise as being productive of some effects interesting to the workmen.

It has been frequently observed, that when thermometers prepared with different fluids, as quicksilver, spirit of wine, water, and oil, have two distant points of heat marked equally on them all, and the spaces between divided into an equal number of parts; the heat, which makes the fluid in one expand to any of these intermediate points, shall raise that in another above the corresponding division, and in another not so high. It was probably this irregularity in the expansion of the fluids, that prevented the agreement of the mercurial and spirit thermometers which Boerhaave says he had made for him by Fahrenheit: the different expansions of different kinds of glass, to which the ingenious artist has recourse in order to account for the variation, appears to be insufficient for producing it; since, if the expansion of the two tubes be always uniform, or in the same proportions to one another, the quantity of this expansion cannot influence the apparent proportional expansions of the fluids. I have seen a mercurial and spirit thermometer very nearly correspond, at different divisions, from the freezing point to the heat of melted wax: the divisions

visions on the mercurial one were all equal, those of the other widened upwards; as if heated spirit either expanded more, or heated mercury less, by a certain additional heat, than the same fluids do by an equal addition of heat made to them in a colder state. Reaumur says, that water from freezing to temperate expands only one tenth part as much as spirit does, but that from freezing to boiling it expands half as much as spirit in the same interval. Though the difference in the proportion at different periods of the heat is doubtless very considerable, I apprehend it does not amount to quite so much as this; and that the mistake arose from supposing the full heat of boiling water to have been communicated to the spirit thermometer immersed in it for a little time; whereas spirit cannot bear so great a heat as that in which water boils, and consequently, in this part of the experiment, the spirit was less heated than the water it was compared with. These variations in the proportional expansions of different fluids seem to have been little considered by those who have given comparisons of different thermometers, by reducing the divisions of one to those of the other from only two corresponding points on each.

A more remarkable exception from the general law of expansion is observed in the freezing of water. Though water shrinks more and more, as its warmth diminishes, down to the period of its congelation; yet, at the instant of its becoming ice, it expands into a larger volume, so as to burst the strongest vessels that have been employed for confining it. The floating of ice in water is a necessary consequence, and a convincing proof, of ice being less dense, or more expanded, than water in its fluid state. M. de Mairan, in a dissertation on ice, attributes this increase of the bulk of the water chiefly to a different arrangement of its parts; the icy skin on water being com-

posed of filaments which are found to be joined constantly and regularly at an angle of sixty degrees, and which, by this angular disposition, occupy a greater volume than if they were parallel. He found the augmentation of the volume of water by freezing, in different trials, a fourteenth, an eighteenth, a nineteenth, and when the water was previously purged of air, only a twenty-second part: that ice, even after its formation, continues to expand by cold; for after water had been frozen to some thickness, the fluid part being let out by a hole in the bottom of the vessel, a continuance of the cold made the ice convex; and a piece of ice, which was at first only a fourteenth part specifically lighter than water, on being exposed some days to the frost, became a twelfth part lighter. To this cause he attributes the bursting of ice on ponds.

Wax, resins and animal fats, made fluid by fire, instead of expanding like watery liquors, shrink in their return to solidity; for solid pieces of the same bodies sink to the bottom of the respective fluids, a proof that these bodies are more dense in their solid than in their fluid state. The oils which congeal by cold, as oil olive and the essential oil of aniseeds, appear also to shrink in their congelation. Hence, the different dispositions of different kinds of trees to be burst by, or to resist, strong frosts, are by some attributed to the juices, which the tree abounds with, being in the one case watery, and in the other resinous or oily.

The earthy powders that mingle with water into an uniform paste, exhibit differences, not less strongly marked, in the affections of their volume by drying. The contraction of clay in drying is well known, and allowance is made for it by the workmen, in forming models or other works of moist clay where any exactness is required in the dimensions. I tried pure clay, and mixtures of it with different proportions of sand, all beaten up

with so much water, as made them just soft enough to admit of being formed into long narrow plates : A particular account of these experiments will be given hereafter ; at present it is sufficient to observe, that the plate of pure clay shortened in drying one part in eighteen, while a mixture of the clay with twice its weight of sand, shortened but one part in thirty. It is not known that any kind of earth shrinks so much as clay, and hence the purity of clay may be judged from the degree of its contraction.

Plaster-of-paris on the contrary, diluted with water into the consistence of a soft or thin paste, quickly sets or grows firm, and at the instant of its setting has its bulk increased, as appears from the pretty experiment mentioned somewhere in Boyle's writings, and which I have often tried : A glass vessel being filled with the fluid mixture and closely stoppt, the glass bursts while the mixture sets, and sometimes a quantity of water issues through the cracks. This expansion of plaster-of-paris, in passing from a soft to a firm state, is one of its valuable properties ; rendering it an excellent matter for filling cavities in sundry works, where other earthy mixtures would shrink and leave vacuities, or entirely separate from the adjoining parts. It is probable also that this expansion of the plaster might be made to contribute not a little to the elegance of the impressions which it receives from medals, &c. by properly confining the soft matter, that its expansion may force it into the minutest traces of the figure ; the expansion of the matter doing the same office as the pressure by which wax is forced into the cavities of a seal.

There are grounds to believe, that differences of the same kind obtain in melted metals at the instant of their fixing or becoming solid ; that at this period they do not observe the same laws as before or after it ; and that, while

some of them contract like oily or resinous fluids in their congelation, or like clay in drying; others expand, like congealing water, or like plaster when it sets.

Mr. Smeaton found, in a set of curious pyrometrical experiments, of which an account is given in the 48th volume of the Philosophical Transactions, that from the heat of boiling water to freezing, a rod of zinc shrunk near three times as much as one of regulus of antimony; yet, when the two metals were melted, the regulus of antimony seemed to shrink in fixing considerably more than the zinc. This difference is the more remarkable, as among all the metallic bodies that have been tried, regulus of antimony in its solid state contracts or expands the least, and zinc the most, by equal augmentations or diminutions of heat; whence the excellence of this last for metalline thermometers, and other instruments whose effect depends on their length varying according to the degree of heat.

An elegant phenomenon of the contraction of silver in fixing is often observed at the end of the process of cupellation. When the silver remains fine on the cupel, if the vessel be drawn forwards from the heat, that it may cool somewhat hastily, the surface of the metal suddenly fixing and contracting, squeezes out some of the fluid part within, which issues in little jets through different parts of the solid crust, and sometimes spirts up to a considerable height, hardening in the air as it rises. M. Morel, refiner of the mint at Paris, made several experiments of this vegetation as it is called, of which an abstract is given in the French Memoirs for 1727: to cool the metal the more hastily, he applied a wet cloth to the surface, and at the same time dipt the bottom of the cupel in cold water, by which means he obtained larger and more numerous jets, variously arranged: he observes, that the larger  
the

the quantity of metal, the finer the vegetations are; that a mixture of two parts of lead and one of silver gave finer vegetations than pure silver; that pure lead had its surface perforated too hastily, and that its jets hardened without rising high; that copper is not easily made to vegetate at all, its surface growing so hard as to afford more resistance to the fluid underneath than the bottom of the cupel does, which last accordingly bursts; and that gold, instead of jets which continue fixed at the lower end to the surface of the mass, throws off small round grains, sometimes to the distance of ten inches.

M. de Reaumur, from some phenomena in the casting of iron, suspected that this metal expands in fixing; and accordingly made several experiments, which are related in a paper in the memoirs of the French Academy for the year 1726, for determining whether iron really expands at this period of its cooling, and whether it is the only metal possessed of that remarkable property.

He observes, that lead, tin, copper and silver, cast into ingots, are always concave or depressed on the upper surface, which seems a mark of their having shrunk in fixing. He melted each of these metals, separately, in small cylindrical crucibles, which being quite filled with the fluid metals, a plate of iron was passed over the surface to take off such part as might have risen above the edges: when grown solid, they were all found to have sunk considerably in the vessels; and on melting them again they were found to fill up the space which they had forsaken in cooling. Having melted pieces of each of these metals in separate crucibles, he dropt into them pieces of the respective metals unmelted; they all sunk beneath the surface, and some fell with a thump on the bottom of the crucible: from whence it is plain, that silver, copper, lead and tin, are heavier, or more dense, in their solid

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than

than in their fluid state, and consequently that the melted metals contract in becoming solid. In making the last of these experiments some caution is necessary, particularly with regard to lead and tin : for if these metals are made very hot, the pieces thrown in will melt so fast, that it cannot be judged whether they sink or swim : if not heated sufficiently, they prove so thick, that the excess of gravity of the solid piece will not be able to overcome the tenacity of the fluid, whence the piece will be sustained on the surface, more especially if it is small, and if the skin which forms on the fluid has not been previously taken off.

On trying the same experiments with iron, the event was different. Ingots of iron appeared, he says, not hollow on the surface, but sensibly elevated or convex. Having brought some iron into thin fusion, and carefully cleared the surface from gross matter, he threw in solid pieces of cast iron of different kinds : they all swum, like ice on water, and when pushed down beneath the surface, they immediately rose again ; a proof that the solid pieces were lighter or more expanded than the fluid, and consequently that melted iron expands or increases its bulk in becoming solid. To this property he ascribes the neatness with which cast iron receives impressions from moulds, a neatness wondered at by those who work only in copper or other metals : he says he has seen a hundred and a hundred times, that though iron was poured quite thick into the mould, it nevertheless took the figure well, its expansion forcing it into the smallest cavities : that he has often seen the workmen surprized to find, that it was with the utmost difficulty they could unscrew the moulds in which iron had been cast, while nothing of this kind is ever observed to happen in the casting of other metals : that works of lead, copper, gold, and silver, are always  
found



found less than the moulds, but those of iron equal to them, or a little bigger.

Having found on trial that solid pieces of iron rose to the surface of melted iron, and being thus convinced of the truth of Reaumur's principal experiment; I thought I had sufficient foundation to say, in the foregoing part of this work, page 67, that iron expands in its passage from a fluid to a solid state. Some instances I had seen of melted iron having closely applied and fixed itself to solid pieces by which it was confined, confirmed me in this opinion, and induced me in page 59, in proposing a method of obviating the common imperfections of the rolls for flattening gold and silver wire, by casting a hoop of steel, and after sufficiently forging the hoop, fixing an iron axis within it, to recommend, as the readiest way that occurred for securing the axis, pouring melted iron into the space between it and the hoop.

An ingenious correspondent has since observed to me, that melted iron does not expand in setting, and will not fix itself to the hoop, but shrink from it as other metals would do: that though works of cast iron are indeed generally larger than the mould, yet this increase of bulk does not proceed from the expansion of the metal itself, but from its fluxing and drinking into its surface a considerable quantity of the sand of which the mould is composed, which he judges to have been the foundation of Reaumur's mistake: that large iron works cast in open moulds, as forge hammers and anvils, have considerable hollows on the upper side: that large works cast in close moulds have always a cavity somewhere in the internal part; that cannon balls cannot be cast without such cavities; of which the workmen are so sensible, that in order to avoid as much as possible the inconvenience of the hollow being near the side, they turn the mould upside down  
soon

soon after the metal has been poured in. It is supposed, that as cast iron begins to set on the surface almost immediately on its being poured into the mould, so as to become covered with a solid shell, the cavities must proceed from the fluid part within shrinking while it becomes solid. Several experienced artists have also assured me that the melted iron will shrink from the hoop.

I shall always take the earliest opportunity of acknowledging mistakes, and my obligations to those who shall point them out. With regard to the method of making the rolls, it may be observed, that the disputed property of iron does not affect the essential part of the proposal, which may therefore still deserve attention, whether iron has or has not that property: for though the particular way, recommended for joining the parts, should not answer, the artist cannot be at a loss to find means of supplying the defect, or of fixing an iron axis in a steel hoop.

To satisfy myself in regard to the fact, and to discover whence any fallacy might have arisen in the consequence of an experiment which appeared so decisive, I made some further trials.

A rod of iron being placed upright in the middle of a steel ring, I melted some cast iron, and poured it into the space between them. When cold, the cast iron firmly embraced the rod, but parted without difficulty from the ring, though it had received very neat impressions from some marks on its surface.

I melted a quantity of the iron in a large crucible, and thoroughly cleared it from the gross matter on the surface. When in perfect fusion, I threw into it a solid piece of the same kind of iron previously heated: the piece dropt to the bottom, but immediately rose up again to the top, as wood does in water: being pushed down with an iron rod, it rose again, and continued to float till it melted  
and

and united with the rest. I tried different kinds of cast iron, with the same event. Even forged iron, though considerably heavier than cast iron in its solid state, was found to be lighter than melted cast iron; for it floated on the surface, and when pushed to the bottom, it rose up again, and this repeatedly till it was dissolved by the melted metal. Had the solid pieces barely swum on the top, it might have been suspected that they were kept from sinking only by want of sufficient fluidity in the melted iron: but their constantly rising up from the bottom, seems a proof of their being lighter than the fluid.

It appears therefore that melted iron is really of greater specific gravity, or more dense, than solid iron, and consequently that in fixing or becoming solid, it becomes lighter, or expands into a larger volume; and yet, that when grown cold, it does not press against, or keep distended, the vessel or cavity it was poured into. Nor do these different effects seem to be at all repugnant to one another. It is not pretended that iron expands at any other period of its cooling, than in the instant of its passage from a fluid to a solid state: after this time it contracts like the other metals. The internal cavities are agreeable to this account: the outer surface first expanding and fixing, a vacuity would remain under it if the next did not also expand: a vacuity must necessarily remain at last, which can be filled only by the subsequent contraction; and its not being filled seems to shew that the expansion is greater than the contraction.

To judge in some measure of the degree of the contraction, I melted some cast iron, and poured it into a long narrow iron ingot mould. The ingot proved in some parts convex on the surface, and in others a little depressed: it was shorter than the mould by nearly three parts in three hundred and thirty-two, or one part in a

hundred and ten ; though it had filled the mould in its fluid state, having taken an impression from both the ends. The real contraction must have been somewhat greater than this ; because the mould must necessarily have acquired a considerable heat at the time of the iron's fixing, and consequently in cooling shrunk along with it.

I have mentioned above that I had seen instances, in which melted iron applied itself firmly to unmelted pieces by which it was confined. The foregoing observations occasioned me to recollect the circumstances in which those instances had happened, and indeed naturally point them out. Cast iron shrinks from an iron or steel ring, which it filled and distended at the time of its fixing : but if this ring be previously made very hot, it might be presumed that its shrinking would keep pace with that of the cast iron, so that the latter would still continue to fill it.

Accordingly I heated the ring to a strong red or rather white heat ; and placing it on a bed of sand, poured into it the melted iron : when cold, the cast iron filled the ring, and was firmly applied to it, so as to be in no danger of being separated or moved by any force that the rolls for flattening gold or silver wire are designed to undergo ; though the juncture was not, perhaps, sufficiently strong for resisting so great force as other rolls must necessarily bear in the flattening of larger metalline masses.

This last experiment is entirely agreeable to, and seems to confirm, the foregoing. For though the ring or mould be supposed heated even to the degree in which cast iron sets ; yet, if the melted iron shrunk in setting, it would have become less than the mould, and continued so in the subsequent period of the cooling.

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## V. Of the blowing of Air into Furnaces by a Fall of Water.

**T**HE earliest method of animating the large fires of the furnaces for smelting ores, appears to have been by exposing them to the wind. Such was the practice of the Indians of Peru before the arrival of the Spaniards in that country. Alonso Barba relates, that their furnaces, called guairas, were built on eminences, where the air was freest; that they were perforated on all sides with holes, through which the air was driven in when the wind blew, which was the only time the work could be carried on; that under each hole was made a projection of the stone-work on the outside, and that on these projections were laid burning coals, to heat the air before its entrance into the furnace. Some authors speak of several thousands of these guairas burning at once on the sides and tops of the hills of Potosi.

I have been informed, that several remains of a like rude process are to be seen in some parts of our own country. The old blomery hearths, as they are called, for the running down of iron ore, are all on the tops of hills; a situation which can scarcely be supposed to have been chosen on any other account than for the conveniency of the wind, being, in other respects, extremely incommo-  
dious.

The gradual succession of bellows to this precarious and insufficient way of supplying air, and the gradual improvements made in the structure and manner of working of the bellows, cannot perhaps be traced. It appears, that at some of our iron furnaces and others, the bellows were formerly moved by a handle as those of the smith's forge, or by the pressure of the foot upon a treadle, or by other means requiring the strength of men : and that, since the force of water has been called in aid to move them, the quantity of ore run down has not only been far greater, but the separation of the metal more complete ; infomuch, that great part of the iron now prepared at some considerable works, particularly in the county of Gloucester, is no other than what had been formerly left in the slags or cinders for want of sufficient force of air.

The bellows used at our furnaces are composed of two boards joined by leather, nearly in the same manner as the common bellows. A cheaper kind of bellows, made entirely of wood, was introduced at the furnaces of the Hartz forest in Germany, according to Schluter, about the year 1620, and has since been received in Sweden and some parts of France. It consists of two long boxes, of the same figure with the smiths bellows, one of which drops over the other, and is of such depth, that when raised up on a hinge as high as it is intended to be, it nowhere comes entirely off : the air enters by a valve as in other bellows, and is forced out by pressing down the upper box : along the edges of the lower or inner box are placed laths, which slide horizontally in grooves, and to which are fitted springs capable of pressing them an inch or two beyond the box, so as to form a ledge, of variable width, which always accommodates itself to the  
outer

outer box, and in great measure prevents the air from escaping between them.

Though the wooden bellows have an advantage above the leather ones of being less expensive and more durable, they have considerable defects ; for it is scarcely possible to make the junctures so tight as to allow no exit to the compressed air, and the friction must necessarily be very great. Some have therefore had recourse to water, for doing the office of the under board of the bellows. A bellows on this principle is described by Mr. Triewald in the Philosophical Transactions, and I have been favoured with descriptions and drawings of two singular ones, now used at some of the iron works in this kingdom, one for the sinery, the other for a large iron furnace, in which the fuel is coak, and which requires the greatest force of air of any known kind of furnace. An account of these will be given hereafter.

There is another method of applying water, so as to produce a strong blast, by means more simple than any of the foregoing, and at little expence. A stream of water, falling through a pipe, in certain circumstances, carries air down with it ; and this air, afterwards disengaged from the water at the bottom, may be so collected, as to have no other vent than a pipe which shall carry it to the furnace.

Machines, constructed on this foundation, though little known among us, are used in different countries, instead of bellows, for animating the large furnaces. But their structure and principles of action have hitherto so little undergone a scientific examination, that those, which have been found to answer the best, may be presumed to owe their excellence merely to chance, and that the workmen have often laid the greatest stress upon the proportions of parts which are inessential. These machines

are doubtless capable of being much improved, so as to produce greater effects, with a less quantity, and what is of more consequence, with a less fall of water : and principles may doubtless be discovered, by which their structure may be regulated, and their power ascertained.

The importance of procuring commodious and cheap means of supplying the vast quantities of air which the smelting furnaces require, induced me to examine the several accounts that have been published of these simple substitutes to bellows ; and to make sundry experiments for bringing them nearer to perfection, and for establishing their laws of action.

## S E C T. I.

*Account of the principal machines used for blowing air into furnaces by a fall of water.*

### I. *A simple pipe.*

**T**HE first account I have met with of a machine for propelling air into furnaces, by a fall of water carrying down air with it, is of one at the copper or brass furnaces at Tivoli near Rome, of which a description and figure are given in the third number of the Philosophical Transactions, and in the *Journal des sçavans* for the year 1666.

A square wooden pipe, of considerable width, and open at both ends, is placed upright. A stream of water runs in at the top, and is discharged at the bottom ; and about the middle of the height of the pipe a smaller horizontal one is inserted, which reaches to the furnace, and is said to convey to it a strong blast of air.

From so imperfect a description, we can learn little of the nature of the machine, or of the manner in which the blast is produced. It may be presumed that the water,



ter, running forcibly against the side of the pipe, as it appears to do in the figure, is in great part dashed into drops; the intervals between which being filled by air, this air is successively pushed down by the drops which follow, and afterwards escapes as soon as it meets with a vent. There seems, however, to be either some inaccuracy in the description, or some essential part omitted: for in such trials as I have made, when air, thus conveyed into a perpendicular pipe along with running water, was discharged by a lateral aperture, part of the water always accompanied it in a stream; and more of the water seemed to issue out in proportion as the quantity of air introduced was the greater.

## II. *A pipe with air holes, inserted into an air vessel.*

M. BELIDOR, in his *architecture hydraulique*, gives a more particular description of a water machine used in some parts of France: he says there are four or five forges on the river Isere, between Romans and Grenoble, which have no other bellows.

The stream is divided into two channels, and each division falls into an upright pipe ten or twelve feet high. Near the tops of the pipes are several holes, made sloping downwards from the outside to the inside: through these holes air enters, and is carried down by the water; though the experiments in the following section will shew, that the quantity of air thus introduced is not so great as in the dispositions mentioned hereafter.

The essential difference of this instrument from the foregoing consists in its having an air vessel, or reservoir for the air, at the bottom. An oval wooden tub, near seven feet high, and three or four feet wide, is inverted, and its lower edge let into the ground five or six inches. The

lower ends of the two upright pipes enter into the top of the tub, and under each pipe is a kind of small stool which the water falls on. The water loaded with air, dashing against the stool with great velocity, rebounds, and its air is disengaged: a pipe communicating with the top of the tub carries the air to the furnace, while the water runs out at a hole in the lower part; a sufficient height of water being kept in the tub, above this hole, to prevent any air from escaping by it.

III. *A funnel and pipe without air holes, inserted into an air vessel.*

M. MARIOTTE, in his treatise *du mouvement des eaux*, gives an account of another contrivance for blowing fire by a fall of water, which Belidor says, from the information of a friend who travelled in Italy, is used in the Tiburtine mountain near Rome, and near Salan on the lac de Garde.

A wooden or tin pipe, fourteen or fifteen feet high, and one foot in diameter, has its lower end fixed into an air vessel or inverted tub, as in the preceding article, from one side of which a blast-pipe goes tapering to the furnace.

The upper end of the large upright pipe is contracted to an aperture of three or four inches, into which is fitted a funnel, whose neck exactly fills it. Into the funnel there falls a stream of water, from the height of ten, fifteen, or twenty feet; which we may presume to be dashed into drops in its fall, and to push down air before it on the same principle as in the machine of Tivoli already mentioned.

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This instrument promises to be more effectual than either of the preceding, though in this country it can be of little use, so high a fall of water being rarely to be procured, at least in those places where smelting furnaces are established.

IV. *A funnel and pipe with air holes, inserted into an air vessel.*

*At Lead hills in Scotland.*

IN N<sup>o</sup>. 576 of the Philosophical Transactions, in the year 1745, Mr. Stirling describes a machine erected in Scotland, for blowing air into the furnaces in which lead ores are smelted; and for conveying fresh air into the works, so as to save the trouble and expence of the double drifts and shafts, and the cutting of communications between them.

A stream of water runs into a wooden funnel, so as to keep it always nearly full: the height of the funnel is five feet, and the diameter of its throat three inches and a half. The neck of the funnel is inserted into an upright pipe, whose diameter is five inches and an half, and its length fourteen, fifteen, or sixteen feet: immediately under the throat of the funnel, four air holes are made in the pipe, at equal distances round it, about an inch and a half wide, sloping downwards from the outside to the inside.

The lower end of the pipe enters into a wooden tub, close at top, but without a bottom, six feet high and five and a half wide, sunk into a pit dug in the ground, and well rammed about with clay: in the middle of the tub, directly under the pipe, is a flat stone about two feet high, for the water to fall upon; and into the top of the tub is fixed a wooden pipe for carrying off the air, com-

municating at the further end with an iron one which enters the furnace : for regulating the blast, a small hole is made in some convenient part of the pipe, which is stopp'd with a pin, or opened, according as the blast is required more or less strong. The hole in the lower part of the tub, by which the waste water passës out, is about five inches square ; and one side of the pit, where the water runs off, is a little lower than the surface of the stone, so that the water can never rise high enough in the tub to cover the stone ; though it is supposed to continue always a considerable height above the top of the hole.

Though this machine is said in the Transactions to be sufficient for the smelting of harder ore than any in Lead-hills where it was erected, I have been informed by a person concerned in those works, that it has since been found not to answer so well as could be wished, and that accordingly it has been laid aside, and its place supplied by the common bellows.

*In Dauphiny in France.*

THE blowing machines used in Dauphiny for the forges and smelting furnaces have a great resemblance in their general structure to the foregoing. They are described by Swedenborg in the second volume of his *regnum subterraneum*, but with little exactness : a more accurate description and figures of them, taken from the papers left by Reaumur, are inserted in the *art des forges & fourneaux à fer*, published last year by the direction of the French academy.

The upright pipe is generally between twenty-five and twenty-six feet high : it is composed of two pieces of fir, hollowed, and joined together by iron work. Instead of a distinct reservoir or funnel on the top, a part

of the pipe itself is hollowed so as to perform the same office : at the top it is twelve inches and a fifth in diameter (English measure) from thence it grows narrower to the depth of nearly thirty-four inches, where its width is only about three inches and three quarters : immediately below this part, called the choak, its cavity widens to nearly eight inches and a half, and this width it preserves throughout the rest of its length. Under the choak are ten air holes, six of which are in one horizontal plane, at equal distances from one another, and the rest about three inches and three quarters lower down : all the holes are cylindrical, near two inches in diameter, and cut at such an obliquity, that the orifice of the upper ones is on the inside of the pipe eight inches, and on the outside only five inches, below the choak.

The tub or air vessel, which receives the lower end of the pipe, is five feet and a half, or a little more, in depth, and nearly as much in width : the pipe enters into it about seventeen inches : about the middle of its height is a flat stone or iron plate, supported by cross bars of wood. The air passes off, as already mentioned, through a pipe inserted into the upper part of the tub, and the water through a hole at the bottom : on the outside of this hole is fixed a wooden frame, with an upright slider, by which the aperture for letting out the water may be occasionally increased or diminished. The blast is regulated, and the air suffered to escape when it is not wanted, by a hole in the blowing pipe, to which is fitted a valve or a stopper.

One of these machines is said to be sufficient for the forge or iron finery, and two or three for the furnace in which the iron ore is run down.

*In Foix in France.*

IN the county of Foix, the blowing machines, as described by Reaumur in the *art des forges* above quoted, are considerably different from the foregoing. The pipe is rectangular, and the part above the choak divides into three funnel-shaped partitions. On the top is a reservoir or cistern of water; and two of the partitions, close on all sides, pass up above the surface of the water, for carrying down air, and thus supplying the place of the lateral air holes: the water enters into the third partition, which is only the space between the two foregoing, and which has but two sides, formed by the two opposite sides of the others.

The author makes the principal difference of these machines from those of Dauphiny to consist in this disposition of the upper part: but the plate, annexed to his description, shews another, which is, perhaps, more material to the effect of the instrument. The whole height of the pipe, including that of the water in the reservoir on the top, is, according to the scale, twenty or twenty-one feet, and the choak or narrow throat is almost down at the middle of this height; so that the water issues through the choak with a velocity which it acquires from a pressure of about ten feet, which is greater than in the machine of Dauphiny in the proportion of about eleven to six: the quantity of water seems also to be much less in proportion to the width of the pipe, the great pressure probably occasioning it to spread, so as to fill a larger bore than it could do when falling with less velocity.

Two pipes, divided in the same manner at the top, are fed by one reservoir: the lower ends of the pipes enter into one large oblong box, from which the air and water pass out as in the foregoing machines.

*At St. Pierre in Languedoc.*

MR. BARTHES, in a curious paper printed in the third volume of the memoirs of the correspondents of the French academy, gives a minute description, though in some parts not so clear as could be wished, of a blowing machine at the forge of St. Pierre on the river Obriou, which he looks upon as one of the most perfect of the instruments of this kind. Its general structure is nearly the same with that of Foix, but the height of water above the choak much less.

The upright pipe is square, about nine feet high, and somewhat more than seven inches wide. Into its top are inserted, at opposite sides, two pyramidal air pipes, widening upwards, and passing up obliquely through a basin of water four feet high. The space included between the pipes, at their lower end, under the basin, is a kind of hopper, into which the water enters through two apertures in the bottom of the basin: to each of these apertures is fitted a piston or stopper, hung to the end of a lever, by which it is raised more or less, according as more or less water is required. Two of these instruments are furnished with water from one basin; and the lower ends of both enter into one air vessel, which is near five feet high, about six and a half long, near three and a half wide at one end, and not quite two at the other. The stones, for the water to fall upon, are somewhat less than four inches and a half distant from the pipes: the water runs off through two rectangular apertures at the bottom, each about eight inches and a half wide, and near six inches high: the pipe which carries off the air, is an inch and a quarter in diameter at the small end where it enters the furnace.

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The obscure part of the description relates to the hopper, and the apertures by which the water is discharged from it into the perpendicular pipe. The hopper seems to be divided into two upright partitions; and there are "two horizontal rectangular openings, through which the water runs into the two hoppers, each of them about seven inches and a half long, and in width five inches and a half, measured on the level of the bottom of the reservoir, which width is reduced to four and a half at the extremity of the air pipes, where the hopper also terminates."

The author observes that in this machine, the water, issuing from the hopper, is necessarily reduced into drops. To satisfy himself more fully of this particular, he took a tin vessel, eight inches and a half square and six and a half high: in the middle of the bottom he cut a rectangular opening, about an inch and a tenth long, and eight tenths wide: to the two long sides of the slit he soldered two tin plates, inclined to one another, and a third across them. These apertures, he says, represent those of the machine when the stoppers are drawn up; and water put into this vessel came out always, during the whole time of its running, in streams which struck against and crossed one another, and which, after spreading, were reduced into drops.

In this illustration of the machine, though it seems clear, there must be something which escapes my apprehension. Having cut an aperture of the above dimensions in the bottom of a vessel, I fitted to each of the longer sides a plate half the width of the aperture, both of which plates were moveable, and kept at different inclinations by means of the third plate which passed across the middle of the two. The vessel being filled with water, I could not observe, as indeed was expected, the  
least



least crossing of the streams that run through it : on the contrary greatest part of the water issued in two opposite directions, horizontally, from between the ends of the plates.

## S E C T. II.

*Experiments and observations for the improvement of the foregoing machines, and for establishing their principles of action.*

I. *Of the quantity of water they require, and the quantity or force of the air they afford.*

**T**HE quantity of water may be estimated with sufficient exactness, from the height of the water in the funnel or basin on the top, and from the width of the choak or throat of the funnel, through which it is pressed by the force of a column of that height.

Defaguliers found, by an experiment often repeated, that the quantity of water running through a square inch hole, twenty-five inches under the surface, is five tons and a fifth in an hour, the ton containing two hundred and fifty-two gallons. The quantities discharged through equal holes at different depths being as the square roots of the depths, and the quantities through different holes at equal depths being as the areas of the holes ; it will appear on calculation, that in the machine at Lead-hills, whose funnel is five feet high, and its throat three inches and a half in diameter, the expence of water is somewhat more than seventy-seven tons in an hour, or near three hundred and twenty-four gallons in a minute ; and that in the machine of Dauphiny, where the height of water in the funnel is only about half as great, and the bore of the throat a little wider, the quantity of water is about two hundred and sixty-six gallons in a minute. Perhaps the real quantity of water may be somewhat less than this calculation

calculation gives, as the resistance of the compressed air may occasion some retardation of the motion. Of the other machines, the descriptions are too imperfect or obscure for any computation to be made from them.

The water, issuing from the narrow throat of the funnel with great velocity, is said to spread so as to fill the wider bore of the pipe, and to become frothy from the mixture of air with it. The jet thus enlarged may be conceived as consisting of a multitude of slender streams or drops, the intervals between them being occupied by air, which is continually supplied through the air holes, and pushed down by the succeeding drops or streams. It has therefore been reckoned, that the volume of air which passes down the pipe must be as much greater than that of the water, as the transverse area of the jet, when spread and reduced to drops in the pipe, is greater than when it passed through the throat of the funnel. Circles being to one another as the squares of their diameters, the area of the pipe of the Lead-hills machine will be to that of the funnels throat as eighteen to twelve and a quarter: the volume of air, according to the above principle, being to that of the water in the same proportion, and the quantity of water nearly 324 gallons in a minute, the quantity of air in a minute should be about four hundred seventy-five gallons and a half, or 134000 cubic inches, or seventy-seven cubic feet and a half. In the same manner, the machine of Dauphiny will be found to yield about 1080 gallons, or upwards of 304000 cubic inches, or 176 cubic feet, of air in a minute: so that by this way of reckoning, the Dauphiny machine, with near a fourth less water than that of Lead-hills, should produce more than a double quantity of air.

But tho' this method of computation appears specious, it is not perhaps to be much depended on; air, in different

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ent circumstances, occupying very different volumes, in virtue of its great compressibility : nor is it certain that the bores of the pipes are sufficiently filled, so as to carry down the full quantity of air. It may be presumed, that the air, intermingled in the jet, is always in some degree compressed by the water ; so that the interstices between the streams or drops contain more air than equal spaces of the atmosphere. It may be judged however from the above comparison, that the wider the pipe is, in proportion to the funnel's throat, provided the water running through the throat will spread through the whole extent of the bore of the pipe, the more air will be carried down.

Mr. Barthès, the only person I know of who has examined these machines philosophically, and endeavoured to improve them, gives a method, in the memoir above-quoted, of comparing the proportional quantities or forces of the air in different blowing machines, on another principle. From considerations too abstracted to be here particularized, he deduces a general rule, that the produce of air will be in all cases in proportion to the quantity and velocity of the water : so that the quantity of water and height of the fall being given in two machines, and the volume or force of the air afforded by one of them being measured by experiment, the volume or force of the air in the other may be determined by the rule. Accordingly he made several experiments of this kind in two machines ; measuring the force of the air, when the water in the basin was at different heights, by the weight, which the blast acting on the arm of a balance, was capable of raising. Taking one of these experiments for a standard, he computed by the rule what the results of the others ought to have been ; but the experiments and calculations agreed ill together. And indeed the rule

does not seem to be applicable but in circumstances, which can scarcely be expected to occur; for it supposes the machines to be all perfect, and every drop of the water to have its utmost effect, or to carry down with it as much air as it is capable of doing; which cannot be admitted to be the case in any of the blowing machines yet constructed.

In the *art des forges* are mentioned some observations of Reaumur of the quantity of air afforded by the wooden bellows. He finds that those used at the iron furnaces yield 98280 cubic inches, or upwards of five cubic feet of air at every stroke; and, including the two bellows, which act alternately, 240 strokes in a quarter of an hour; which, on a reduction of the French measures to the English, make 1301896 cubic inches, or upwards of 753 cubic feet, in a minute: this quantity exceeds that which the foregoing calculation gives for the machines of Dauphiny above four times, and therefore four of the machines should scarcely be able to supply the iron furnace with so much air as the wooden bellows does; whereas two or three are said to be sufficient. Again, the bellows of the iron finery and forge was found to give two thousand fifty-one cubic inches and a third at each stroke, and four hundred and twelve strokes in a quarter of an hour; whence the quantity of air in a minute is 458247 cubic inches, or somewhat more than 265 cubic feet: this is greater than the calculation of the water machine, in the proportion of about three to two, tho' one of the water machines is found to supply the office of the bellows.

It is not to be supposed, that the quantity of air, which furnaces require, is confined to any such precise limits, as that two bellows, from their being found to answer sufficiently for one kind of furnace, or even for one individual furnace, can be concluded to yield quantities of

air exactly or nearly equal. The above differences are perhaps as little as can be expected in comparisons of this kind where the effects compared are so indeterminate.

As to the water machines, it is plain, that the quantity of air carried down cannot be greater, than the spaces between the drops or divided streams in the pipe can contain ; and that though the air in these spaces must be considered as being compressed to a certain degree, yet it cannot be supposed compressed into two thirds of its natural volume, which would be necessary for making the calculations of the wooden bellows and the blowing machine to agree, because such a condensation would require the weight of a column of water of eleven or twelve feet, or the third part of such a column as is equivalent to the pressure of the atmosphere ; whereas in the Dauphiny machine, though the air was pressed down with the full force of the column of water above the choak, the height of this column is less than three feet, and could not condense it more than one twelfth part.

In what manner Reaumur computed the air of the wooden bellows, we have no account : it is probable that he judged, as others have done in the same cases, from their capacity ; supposing the whole quantity of air they contained to be delivered at every stroke. If so, we can lay no stress on the computation, for neither the wooden nor the leather bellows deliver their full contents of air ; a considerable space remaining full of air when the bellows are closed ; and this space containing considerably more air than an equal volume of the atmosphere, on account of the air being condensed in it by the pressure of the bellows. I have been informed by a judicious workman, that the bellows of the iron finery retains commonly a third, and sometimes half of its air ; and that when lined

with wood, so that as little vacant space as possible might be left, he found it to blow much stronger than before.

The strength of bellows is best judged from the force of the blast itself; and this force may be determined, in the method recommended by Mr. Barthès, already mentioned, by the weight it is capable of raising. He found that in the blowing machine of St. Pierre, described at the end of the preceding section, the force of the blast issuing from a hole of an inch and a third in diameter, raised the arm of a balance loaded with a weight of twenty-five ounces and a half. He gives some other experiments, of comparing the proportional diminution of its force according to the diminution of the height of the water; which I shall here insert in the original French measures, to avoid unnecessary fractions. The above force of twenty-five ounces and a half is the maximum of this machine, produced by the full quantity of water in the basin, or a height of forty-eight inches above the choak: with a height of forty-one inches, the weight raised was twenty-two ounces; with a height of thirty-two inches, nineteen ounces; with a height of twenty-eight inches and a half, seventeen ounces and a quarter; with twenty-four inches and a half, fifteen ounces and a quarter; with nineteen inches, twelve ounces and three eighths; with sixteen inches and two thirds, ten ounces and a quarter; and with a height of thirteen inches and a half, eight ounces and three quarters.

It may be observed, that in some of these experiments the water must have been employed to disadvantage; and that by increasing the height of the water much further than the above limits, in the same machine, we could not expect to produce proportional augmentations of the force of the blast: for if a certain quantity of water, running with a certain velocity through the choak, be supposed

posed to fill the bore of the pipe ; a less quantity, with a less velocity, must leave a vacancy, which will suffer part of the air to escape ; and a greater quantity, with a greater velocity, must have some part of it spent ineffectually, for want of sufficient room to spread. Some experiments mentioned hereafter afford a clear proof of this.

The force of the air may be determined in an easier and more simple method, by means of a glass pipe, open at both ends, with one end fixed in a basin of water. The basin may be hung in the upper part of the tub or air-vessel of our water machines, and the glass pipe let into it through a hole in the top, what space may remain between the pipe and the hole being properly closed : the pressure of the air on the surface of the fluid in the basin, forces part of it up into the pipe ; and this ascent will always be the measure of the power or density of the air. Water is here greatly preferable to the quicksilver used in the same intention on other occasions, as it discovers smaller variations in the force ; for being fourteen times less ponderous than quicksilver, an equal pressure forces it fourteen times higher in the pipe : the whole ascent of quicksilver, by the pressure of the air in bellows, is so small, as frequently not to exceed that part of the pipe which is inserted into the tub. Instead of a glass pipe, a copper or iron one may be used ; and the ascent of the water measured, either by occasionally dipping a rod in it, or by means of a hollow copper ball, or other floating body, with a stem standing out of the pipe, and a proper weight below to keep it upright. It must be observed, that the height of the water in the pipe is to be estimated from the surface of the water in the basin : whence the pipe ought to be of small bore in proportion to the basin, that the water may not fall considerably in the basin by the loss of that which rises in the pipe.

Dr.

Dr. Hales found that a smith's bellows raised a mercurial gage about an inch, so that it would have raised a water-gage about fourteen inches. The twenty-five ounces and a half, raised in M. Barthès's experiment by the blast of the machine of St. Pierre from an aperture of an inch and a quarter bore, English measure, are equivalent to the ascent of water in the gage pipe forty or forty-one inches. I have been informed, that the pipe by which the air is discharged into our iron furnaces is at least of an inch and a half bore; and that the air, with this aperture to pass off by, ought to be of as great density as it can be reduced to by the human breath in a confined space; which is such as to raise the water in the gage about fifty inches; in which case it is compressed into near an eighth part less volume than it commonly occupies in the atmosphere. But the quality of the fuel and other circumstances occasion such variations in this respect, that no general standard can be laid down. I have been assured, that a charcoal fire will be excited as strongly by such a blast as raises the gage thirty-six inches, as a fire of coaked pitcoal will be by one of fifty inches.

## II. *Observations on the air vessel.*

THE structure of the air vessel, or tub at the bottom, is in great measure independent of that of the rest of the instrument; the same air vessel serving equally for different kinds and sizes of these machines, while the perfection of the other parts consists in their adjustment and proportion to one another. The office of this vessel being only to serve as a reservoir for the air, and to suffer the waste water to pass off, no great care seems to be needful for regulating its dimensions; and as the stone, which is placed in it under the pipe, serves only to receive  
and



and support the fall of the water, or to occasion the water to be dashed into small particles, that the air may be the more effectually extricated, its distance from the pipe seems also to require no exact adjustment. There are however some particulars, in regard to the size of this vessel, and the disposition of some of its parts, which appear to deserve attention.

The gage, mentioned in the preceding article, will be an useful addition to it; shewing at all times by inspection the force of the blast, and thus enabling the workman to judge whether it is sufficient for the purposes intended, and giving him notice of any failings or imperfections that may have happened in the machine; as whether any air escapes through the joints or cracks, or whether the choak or throat of the funnel is obstructed by stones or other matters brought by the stream.

All the writers I have met with, who give any account of these kinds of blowing machines, seem to suppose the water within and without the air vessel to be upon a level. But as the air in the air vessel is so far compressed, as to be able to raise the water in the gage to a considerable height, it must necessarily act with equal power on the water below it; and if this water can pass off freely at the bottom, it must be depressed as much as that in the gage pipe is raised. The water within and without the vessel is exactly in the same situation with that in the basin and pipe of the gage; excepting only that the former receives a continual supply within, which passes off as fast on the outside. The excess of the height of water on the outside of the vessel, above that of the water within, appears to be the very power by which the air is compressed and driven into the furnace.

To be further satisfied of this depression of the water, I used, for the air vessel of a small machine, a tall glass,  
without :

without a bottom, seven or eight inches of its lower part being immersed into a tub full of water. As soon as the machine began to play and the gage to rise, the water within the glass sunk lower than that in the tub on the outside; and the depression of the water and rising of the gage were, as nearly as could be judged, equal, and kept pace with one another. In a little time the water was forced quite out of the glass, and the air following it rose in bubbles to the top of the tub.

The bottom of the air vessel ought therefore to be sunk at least as much below the level where the external water passes off, as the gage is expected to rise; for otherwise, before the air is sufficiently compressed to raise the gage to the due height, it will force all the water out below, and in part escape itself by the same aperture. Hence the depth of the air vessel, in any of these machines where the water has a free passage at the bottom, gives a power which the force of the blast in that machine can never be made to exceed: thus at Lead-hills, the water being only of the height of two feet from the bottom of the vessel to the level of the bank where it runs off, the air can never be compressed further, than to be able to support a column of two feet of water, or to raise the gage to that height; whereas in the machine of St. Pierre, the compression is about two thirds greater.

The sinking of the water in the air vessel may indeed be prevented, by making the aperture at the bottom, through which the water is discharged, of such a size, that the pressure of the air may be able to drive through it no more water than is received at the top. But such an adjustment would be apparently very difficult; and tho' it should be exactly hit, yet, if the quantity of water received was not always the same, it would scarcely be possible to

avoid either a depression or elevation of the water in the air vessel.

Though the depth of water be sufficient to resist the pressure of the air, it will be easily conceived, that if there was no solid body to support the fall, the great force of the stream, falling from such a height, would push down or dash about great part of the water in the bottom, so that the air would get at the hole, and in part make its escape with the water. It may be presumed that even the drops of water, rebounding from the stone, and falling down again, have a like effect, though in a lower degree: for drops falling through the common atmosphere into water, carry air with them, which afterwards rises in bubbles, as may often be observed in heavy rains; and it is not to be supposed, that the drops should not here also carry into the water some of the compressed air, which surrounds them and is entangled between them. Though part of the air, which thus passes into the water, doubtless rises again in bubbles, as appeared in using the glass air vessel above mentioned; yet part may also be pushed so low, as to escape through the hole, and discover itself by bubbles in the water on the outside of the vessel, which I several times observed before the water was driven entirely out of the glass.

Mr. Barthès likewise takes notice of air being thus carried down into the water by the drops, or introduced into the cavities which they form in falling. In order to prevent it, he recommends making a partition across the tub, at the level of the stone, with only a hole at one side, and this in the part most remote from the pipe through which the water falls: the rebounding drops are received upon the board, and run off gently through the hole into the water underneath.

The inconvenience may be prevented also, as effectually, and with more advantage in other respects, by making the air vessel of a very considerable depth below the surface of the stone : it may be sunk several feet into the ground below the level of where the outward water runs off, so as to have always a column of water in the vessel, of any height required, or of a height which shall secure against any air passing down to the bottom. This structure would free the workman from any care about increasing or diminishing the aperture, or regulating the height of the water. For if the deep vessel has an aperture in its lower part, large enough to discharge all the water that can fall into it through the pipe in the top, or, for the greater security, a good deal larger, its magnitude being of no inconvenience ; if this vessel is sunk in a pit of water up to the level of the stone, or to a certain height above it ; and if the pit has a drain sufficient to carry off what more water it may receive : we may be sure that the water will be always high enough in the vessel, because the pressure of the water on the outside will keep it so ; and that the pressure of the air within the vessel will always keep it below the surface of the stone.

The air extricated from the water is always moist : when let off at a little way above the stone, I have often observed it to leave drops like dew on any solid body opposed to it. A small degree of moisture may perhaps be of no disadvantage ; but such a degree as this must doubtless be injurious, and render the air of less efficacy for animating the fire.

In the water machines of Dauphiny, inclined plates are said to be placed at the entrance of the pipe which carries off the air, to keep back the watery drops. M. Barthès proposes letting the air off into another vessel, in  
which

which sponges are to be hung for imbibing its moisture, and in the bottom of which a cock is to be fixed for occasionally letting off the water that drops from the sponges. I apprehend the intention may be more effectually answered, by making the air vessel of a considerable height above the surface of the water : for though the air at the bottom is necessarily loaded with moisture, yet in rising to the height of four or five feet, so much of the water separates and falls down, as to leave the air seemingly of sufficient dryness. The vessel might be made as high as the pipe itself : nor would this large size be of any inconvenience in regard to the blast, for as soon as it is filled with air of a certain density, the blast will continue of the same force as from a small vessel. The joints should be well secured to prevent the escape of any air through them : the stone for receiving the dash of water, should be placed near as much below the level of where the water runs off, as the gage is expected to rise ; and the pipe should reach as low as within five or six inches of the stone. It would perhaps be of some advantage to have the surface of the stone a little concave, so as to occasion the watery drops to be rather dashed backwards towards the stream, than thrown upwards through the cavity of the vessel.

### III. *Experiments of air passing down through pipes with falling water.*

#### *Water running through a crane.*

IN the running of water through a siphon or common crane, when the sucking pipe on the long leg of the crane was stopt, the water, as it issued from the extremity, filled the bore : on opening the sucking pipe, the column of water appeared less than the bore.

Judging that the motion of the water must be retarded in this last circumstance, I measured by a pendulum the times in which equal quantities of water run through the crane in both cases; and found, in many trials, that the quantity which took the time of a hundred swings of the pendulum to run in when the sucking pipe was open, run in ninety-three, and sometimes ninety-two, when it was stopt.

As these differences seemed to proceed from air introduced into the water through the lateral pipe; I tried to make this air sensible, by raising the vessel which received the water from the crane, and keeping the nose of the crane immersed in it. As often as the sucking pipe was opened, air bubbles arose in the water of the receiver, and fresh bubbles succeeded while it continued open; but so long as it was kept stopt, no air bubbles were seen.

To collect the air, a cask without a bottom was sunk nine or ten inches in a tub of water, and the nose of the crane inserted into a hole made in the top of the cask: into another hole in the top was fitted a small pipe for giving vent to the air; and within the cask was fixed an inverted mortar for the stream to fall on. So long as water was kept running through the crane with the sucking pipe open, a sensible blast issued from the blowing pipe of the cask, and a burning coal exposed to it was excited in the same manner as by a common bellows: the sucking pipe being stopt, no blast was perceived, nor was any motion produced in the flame of a candle applied to the orifice.

It appears therefore that water, running down through an upright pipe, and filling its bore, admits air to enter through a lateral pipe: that after this admission, the width of the column of water contracts, the introduced

air occupying part of the cavity of the pipe ; and that this air passes down on the outside of the water, or in a separate column, not intermixed with it so as to render it frothy.

*Water descending through an oblique pipe with lateral apertures.*

I VARIED the foregoing experiment by taking, instead of the crane, a leaden pipe, about ten feet long and three quarters of an inch bore. Several holes were made, at intervals, in the length of the pipe, and small tubes fixed into them like the sucking pipe of the crane. The pipe being laid aslope, its upper end was turned up perpendicularly, and a funnel fitted to it, which was supplied with water by a cock in the bottom of a reservoir : the other end of the pipe, which the water issued from, was inserted into the air vessel used in the preceding experiment.

The lateral tubes being stopt, and the cock so turned as to let the water run fast enough to keep the funnel always full, no air issued from the blowing pipe. On opening the tubes, a considerable blast was perceived ; the water passed slower through the pipe, so that the same stream made the funnel run over ; and on pulling out some of the tubes, and looking in through the holes, the column of water was very visibly less than the bore of the pipe. The tubes being stopt again, the blast ceased, and the stream did no more than keep the funnel full.

A small variation in the circumstances of this experiment made a very material difference in the effect. The supply of water having been diminished, so as to rise only a little way above the throat of the funnel, a pretty strong blast issued from the blowing pipe though all the lateral tubes were closely stopt ; and when the tubes were open, instead of air passing in by them, a blast passed  
out

out from them, the air vessel in this case yielding none ; so that here the air must have been introduced at the top and passed down the funnel, and afterwards escaped where it first found a vent. To be further satisfied in this point, I repeated the experiment with a somewhat different apparatus, in the following manner.

*Water falling through a funnel.*

THE glass receiver of an air pump, about two feet high, open at both ends, had its lower end immersed about seven inches in a vessel of water, and supported at a proper distance above the bottom for the free passage of the water under the edges. A brass plate being pressed close on the top, with leather between, a glass funnel, about twelve inches deep, and above half an inch diameter in the throat, was fixed into a hole in the plate ; and into another hole was fitted a small blowing pipe.

A stopper being introduced into the funnel, till the water it was filled with had become perfectly quiet, and then cautiously removed, the water run in a stream, which falling into that in the receiver, produced air bubbles : but no blast issued from the pipe ; and when the pipe was stopt, the water in the receiver did not sink lower than the level of that in the outer vessel, whereas, if any air had entered with the water, and been compressed in the receiver, it must have forced a proportional quantity of the water out below.

The funnel was then supplied from a pipe, by which the water was made to dash against one side of it. By this means the fluid received a spiral motion, and twirling round the funnel, left a large vacuity in the middle, reaching down sometimes to the funnel's throat. The stream, as it run through, was also twisted ; a sensible blast



blast issued from the air pipe ; when the pipe was stopt, the water in the receiver was forced lower and lower, and was soon driven entirely out, abundance of air bubbles following it into the water in the outer vessel.

When the funnel was kept entirely full: though the stream was directed as before against its side, there were little marks of any air being carried down. And when the funnel was near empty, the effects were also inconsiderable ; the vacuity in the middle of the spiral circumvolutions of the water seeming to reach to the bottom, so as to suffer the air to escape upwards through the hollow column of water.

*Water falling from a considerable height into a funnel with a pipe.*

A LEADEN pipe, six feet high and an inch and a half in diameter, was inserted into an air vessel, with the water gage already described. Into the top of the pipe was fixed a tin funnel, whose throat fitted close to it ; and into the funnel a stream of water was let fall, from a reservoir five feet above, in quantity sufficient to keep the funnel running over. This apparatus represents Mariotte's blowing machine described in the third article of the preceding section.

The water, divided by the fall, pushed down abundance of air with it : a strong blast issued from the blowing pipe, and the gage rose high. On raising up the funnel a little, the stream that issued from it appeared all frothy : as often as the funnel was lifted up, the gage sunk, the air, which had been driven in by the dash of water, escaping between the funnel and pipe : on letting down the funnel close, the gage immediately rose again.

Instead

Instead of a fall of five feet, a stream was directed into the funnel from only about half that height. The gage still rose considerably, though not so high as before.

It is observable, that in the circumstances of these experiments, a twirling motion communicated to the water in the funnel impeded the carrying down of air, the gage always sinking on the water receiving such a motion; whereas, in those of the preceding article, it seemed to be by the twirling of the water that the air was pushed down.

It appears therefore that there are two ways of making air pass down with water through a funnel, one by directing the stream against the side of the funnel, the other by letting it fall from a great height: that in the one case the air enters between the spiral circumvolutions which the water forms in the funnel, and in the other between the drops into which a considerable part of it is reduced by the fall; that we cannot avail ourselves of both ways at once, the one impeding the effect of the other; and that in either case the air holes under the throat, so necessary in other machines, can have no place, as they give a vent to the air brought down from above.

*Water falling from a funnel through a pipe with air holes.*

THE six-foot pipe, used in the foregoing experiment, continuing fitted into the air vessel, its upper orifice was widened, that the small end of a funnel-shaped copper pipe, of the same bore with the preceding funnel, might hang freely in it, without touching the sides. The funnel-pipe reached up to the reservoir, and was kept always full, that the water might receive little or no air but at the vacuity between the nose of the funnel and the leaden pipe.

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In this situation, the quantity of air was much less than in the preceding : the water fell through the funnel in a stream not at all frothy, and the gage rose but a little way. I widened the aperture of the leaden pipe, to let in more air, but still the gage continued low.

Into the orifice of the funnel I inserted a smaller pipe, whose diameter was one inch, and whose area was of consequence less than half of that of the leaden pipe. The blast was now strong, and the gage rose higher than when the water fell from an equal height into the low funnel of the foregoing article. I tried funnels considerably smaller, and found the gage still to rise high : but at last, with one of a quarter of an inch diameter, it did not rise at all, and no blast could be perceived.

One of the funnels which answered best being properly fixed, with two or three inches of its neck hanging free within the wider pipe, I made several variations in the manner of admitting the water and air, with a view to compare the effects of different ways of admission. The funnel being full, and gently supplied so as to keep the water in it as steady as possible, the height of the gage was marked : on giving a circular motion to the water, or letting it fall from a height, the gage always sunk, even a slight twirl or dash sensibly affecting its height. The space between the nose of the funnel and the pipe was stopt, so that no air could enter but at the top : the funnel being now full, and the water quiet, the gage scarcely rose at all ; on twirling the water, it rose considerably, and when the water fell from a height, it rose further, though not so high as the standard mark.

It appears therefore that there are two general methods in which water may be made to carry down air, one in which it receives the air at the top, and the other through lateral apertures ; and that the circumstances, which con-

tribute to the effect in one case, impede it in the other: That water, being at rest in a funnel, and then suffered to run through, carries little or no air with it; that when made to twirl round in the funnel, it carries a considerable quantity; and that when it falls from a height, so as to be in great part dashed into drops, it pushes down considerably more: That running through a pipe with lateral apertures, perpendicularly or obliquely, it receives air through the apertures, even when its motion is slow; that when the pipe is of equal bore throughout, the quantity of air thus received is not great; but that, when the pipe is contracted to a certain degree in the part where the apertures are, the quantity of air is greater than that introduced through the funnel without air holes: That air brought down from the top of the pipe or funnel prevents the introduction of fresh air through the lateral holes, which in this case, instead of receiving more air, discharge that already received.

Finding that the two general methods, by which air is made to pass down with a stream of water, could not be united in one machine; and that the pipe and funnel, with apertures for the entrance of air about or under the throat of the funnel, have the greatest effect; I proceeded to examine the most proper form and disposition of these.

#### IV. *Experiments and observations for regulating the structure of the funnel and pipe.*

##### *Experiments with funnels and pipes of different heights.*

THE water, as already observed, passing through the narrow throat of the funnel, is afterwards enlarged into a jet which fills the bore of a wider pipe.

The quantity of air introduced appears to depend upon the degree of this enlargement, and on the quantity of water that runs through in a given time.

The greater the height of water above the narrow throat, the greater velocity will the jet receive, and the more it will be disposed to spread and be enlarged. The length of the pipe does not appear to be of so much importance: it should seem sufficient if the pipe is of such length, that the pressure of water in it may be able to resist the compressed air in the air vessel, and that after part of its power has been spent in overcoming that force, it may still have velocity enough left to run down as fast as it can be supplied from the funnel. In order to attain to some determinate proportions, the following trials were made.

A leaden pipe, seven feet high, and an inch and a half in diameter, being fitted into an air vessel, as in the foregoing experiments, funnel-shaped pipes of different heights were supported over it, so as that the small end of the funnel might hang freely in the orifice of the leaden pipe, and leave space enough for the entrance of air all round. For the greater security of the throat being of the same area in all the funnels, one and the same copper pipe served as a throat for them all: the funnels being formed by inserting this pipe into larger tapering ones of different heights. The funnels were always kept full, and the water conveyed into them as gently as possible, so as to produce no dashing or twirling motion.

A funnel of one foot high had very little effect: the rising of the gage in the air vessel was inconsiderable, and the stream of air from the blowing pipe was but just to be felt: on opening some holes made in the upright leaden pipe under the throat of the funnel, the jet of water appeared not spread, but rather contracted, and did not fill

the bore. With funnels of two and three feet, the gage rose more, and the jet spread, though it did not appear to fill the pipe, till it had reached about half way down to the bottom. Funnels of five and six feet produced a strong blast, and kept the gage high, the jet filling the pipe before it had fallen a foot below the throat of the funnel.

On many repetitions and variations of these experiments, I have not observed that the jet spread sufficiently with less than a fall of five feet. With a fall of sixty-four inches, the gage rose more than five times as much as with one of sixteen inches, though the quantity of water which run in the first case was only double to that in the latter, viz. as the square roots of 64 and 16: from whence it is plain that the above differences do not depend entirely on the different quantities of water which run through funnels of different heights, but in great part on its different velocity. Some other experiments seemed to confirm this point: for having used short funnels so much wider than the high ones, that the quantity of water discharged by the former was equal to or greater than that by the latter, the short never produced so strong a blast, or raised the gage so far, as the others.

Being satisfied of the advantage of having the funnel of very considerable height, I in like manner varied the length of the pipe. Having made a mark at the part where the gage rose to when the funnel was five feet, and the pipe seven, I added to the pipe about a foot more: the gage scarcely rose any further. A foot being cut off from it, the gage fell a little: two feet being cut off, it fell considerably; and the retrenchment of another foot made the machine of little effect, the gage sinking almost to the bottom, and the blowing pipe yielding but a weak current of air. The pipe, thus reduced to four feet, was tried with a funnel of near eight feet: in this case there was no blast

at all. But with funnels less than its own height, as of two and three feet, it still raised the gage considerably.

It appears from these experiments, that in most of the machines described in the preceding section, the lengths of the funnels and pipes are greatly disproportioned to one another, and consequently the water applied to disadvantage. Those of Dauphiny in France are particularly faulty in this respect, the funnel being scarcely three feet high, and the pipe twenty-five or twenty-six : with so small a height of water above the choak, I have never been able to make the jet spread near to such a degree as it is said to do in the machines of Dauphiny, without particular contrivances for that purpose, which will be mentioned in the sequel of this paper. The Foix machine agrees the best with my experiments : but as the funnels of the others are undoubtedly much too low, that of this seems to be rather too high. The effect appears to be the greatest, when the funnel is about two thirds of the length of the pipe.

*Experiments of the disposition of the air holes.*

IN the foregoing experiments, the simplest and most obvious way of admitting air was chosen, by leaving a space between the funnel and the pipe. The air pipes of the machines of Foix and Languedoc answer the same end, carrying in the air above the surface of the jet of water. As the other machines have the air holes under the jet, I tried what variations would result from this circumstance, and from making the apertures at different depths under the throat of the funnel.

Into a pipe of six feet was fitted a funnel of four feet ; and six inches below the orifice of the funnel, four holes were bored round the pipe, sloping down from without inwards : eight inches lower down, I made another row of holes ;  
and

and at like distances under these, a third and a fourth. To each hole was fitted a stopper which exactly closed it.

All the holes being stoppt, the funnel was first hung free in the pipe, as in the former trials, and the height to which the water rose in the gage was marked. The funnel being then let down into the pipe, so as exactly to close it, the upper air holes were opened : the gage did not now rise so high as before. The upper air holes being stoppt, and the second row opened, the gage continued at its last height. With the third row open, it rose rather higher than the first mark ; and with the fourth it fell the lowest of all.

The several entrances for the air were then opened by two and two. With the space between the funnel and pipe, and the upper air holes, open, the gage did not rise so high as with the space only ; and with the upper and second row of holes it continued at the same height. With the second and third, it rose considerably further, though not up to the first mark ; and with the third and fourth, it fell a little below the preceding height. In all these cases, where two rows of holes were open, the water manifestly did not fill the bore of the pipe at the upper holes ; but spread so as to completely fill it by the time it had reached the lower ones, at which last, part of the water spirted out and carried some of the air with it.

In another pipe of the same size I made two sets of air holes, three inches apart, and the uppermost of them twelve inches from the orifice of the funnel. With the upper row open, and with both rows open, the gage rose almost equally, being only a little lower in the latter circumstance than in the former ; but with only the lower row open, it sunk about one half. These being all stoppt, and another set bored opposite to the orifice of the funnel, the gage rose as high as in the first case.

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These experiments, and several others I have made on the same subject, are not so conclusive as could be wished. They seem to shew that it is more eligible, to have the entrances for the air in one horizontal plain, than in two plains above one another; and either above, or at some distance below the jet, than immediately under it: That they ought to be of greater magnitude than in some of the machines described in the first section, particularly in that of Lead-hills, whose air-holes, taken all together, are not of half the area of the space in the pipe which the air has to fill. They ought at least to be of an equal, or rather of a double extent, that the air may enter the more freely.

*Experiments of the proportional bores of the funnel and pipe.*

WE have already seen, that unless the throat of the funnel is less than the pipe, the quantity of air carried down will be inconsiderable; and that by lessening it further than to a certain point, the effect is also diminished or destroyed. To hit this precise point is not perhaps possible; and the point which is the most perfect proportion for one height of water, cannot be so for any other, an increase of the pressure disposing the jet to spread more and fill a larger bore.

It appears from some experiments already mentioned, that when the whole height of the fall of water is fifteen feet, the height of the pipe ought to be nine feet, and that of the funnel six. This being as low a fall as these kinds of machines have been generally erected for, and as high a one as is generally to be expected in this country, I made several trials for adjusting the proportions to those heights; using for the funnel a tapering copper pipe, into the lower end of which were occasionally inserted smaller pipes of different bores.

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By trying several of these funnels, we came to certain sizes, which could not be much increased or diminished, without diminishing the effect of the machine ; but if there is, in this respect, any exact standard, our experiments did not discover it. There are so many circumstances, as we have already seen, which influence the effect, that it is very difficult to judge, when the differences are small, how far they depend on any particular one. When the area of the orifice of the pipe was from four to five times greater than that of the funnel, the differences in the height of the gage were not very considerable : the due proportion seem to lie within these bounds, and perhaps nearer to the latter than to the former ; for when the funnel was only about a sixth part of the area of the pipe, the gage stood rather higher than when it was a third part, from whence the proportions should be as one to somewhat more than four and a half.

*Experiments of dividing the stream so as to increase its effect, and render less water sufficient.*

As the effect of these kinds of machines depends on the water being spread and divided, and the air, which comes in to fill the interstices between the little streams or drops which compose the jet, being pushed down with velocity by the succeeding water ; I have endeavoured to divide the stream, more effectually than is done in the common machines, and with little or no diminution of its velocity, by varying the form of the aperture of the funnel.

On the orifice of the funnel I fitted a perforated tin plate, like the nose of a watering pot, but with the holes larger, and of a triangular figure ; this figure was chosen on account of its great surface, water, passing through a triangular aperture, having about a third part more surface than  
through

through a circular one of equal area: some more holes were made round the sides, in such positions, that the streams issuing from the higher holes, might nowhere fall upon or coincide with those from the lower ones, but that the water might be uniformly dispersed through the whole cavity of the pipe. By this division of the water it was made to fill a much larger bore than otherwise, and to produce as great an effect as the full quantity of water which the same pipe would otherwise have required; insomuch that quantities of water which had little effect in the common way of application, were by this contrivance made to yield a strong blast.

This method is accompanied with an inconvenience, which often shewed itself in the course of the experiments, and which must be more considerable in the continued working of the machine. After it had acted vigorously for some time, its action frequently abated of a sudden: the blast from the blowing pipe grew weak, and the gage sunk: sometimes its force increased again in a little while, but for the most part it continued to diminish more and more. The cause was discovered to be bits of leaves and other like matters which the water had carried into the funnel, and which had in part stopt up the small apertures. The remedy was obvious, letting the water pass from the reservoir through a wire sieve whose holes were much finer than those in the nose of the funnel; and doubtless an expedient of the same kind would prove effectual for the largest machines. It is in all cases adviseable to have the water pass through a grating before it enters the funnel; even the common large apertures being sometimes choaked up by matters which the stream brings along with it. Where scantiness of water, or want of so high a fall as is commonly required, persuade to this contrivance for procuring a more effectual division of it,

and for augmenting its power with its surface, two or three gratings, or perforated plates, with apertures of different sizes, will be necessary: one with very fine holes, much smaller than those of the cullender, that nothing may pass through the former which can be in danger of sticking in the latter: another with larger apertures, for detaining weeds, and such other matters as would soon obstruct the finer strainer.

I have tried other methods of procuring this dispersion of the water, by making the throat of the funnel of different figures; but with little success. Whether the throat was made converging or diverging, in greater or less degrees, there did not appear to be any material difference in the effect of the machine. I introduced into the funnel a cylindrical core, which was fixed in the middle, by means of pins projecting from it, so as to leave a circular aperture all round it; and this core was sometimes solid, and sometimes a pipe which reached above the funnel and carried down air into the middle of the jet below: but no other difference was observed in either case than what arose from the necessary diminution of the quantity of water. It is probable indeed, that by duly proportioning the core to the funnel, and the width of the pipe to the sheet of water falling round the core, the effect, by this division of the stream, would be made greater than an equal quantity of water would produce when falling in one column; though the increase, obtainable by this method, did not promise to be considerable enough to deserve the troublesome investigation of the proportions. One trial however, depending partly on this principle, appeared of some importance to be made.

As the water machine of St. Pierre is said to have two apertures in the bottom of the funnel, whose streams, as they issue out, cross one another and are dashed into drops,

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I tried to answer this intention, by using for the funnel a wooden trunk, with two of its sides sloping downwards so as to leave a long narrow aperture between them : in the middle of this aperture, and parallel to the inclined sides, was placed a wedge of the same slope with the sides of the funnel, that the water might pass out in two sheets directed towards one another.

The funnel was at top about eight inches square : its width at bottom seven inches and eight tenths by one inch and nine tenths. The wedge, dropt into it, entirely stopt the lower aperture, and had its thin edge hanging down considerably below : slips of wood of different thickneses fastened on the wedge occasionally, two on each side, prevented its falling down so far, and procured spaces of different widths between it and the sides of the funnel ; so that the water could be reduced at pleasure into two sheets, seven inches and eight tenths wide, and from less than a quarter of an inch to three quarters of an inch thick ; the partition in the middle reaching in all cases lower down than that which confined them on the sides, that they might not unite into one upon their discharge from the throat. Along the sloping sides of the funnel were two air pipes, of the same breadth with them, and about an inch and a half wide ; so that at the bottom there were three oblong rectangular apertures, the middle one, with a wedge in it, for the water, and the two lateral ones for air : the outsides were continued about seven inches and a half below these apertures, so as to form a large cavity for the water to spread in.

The funnel, above the throat, was somewhat more than three feet high : on the top was fitted a wooden pipe, nearly of the same width with it, and four feet eight inches high. The top of this pipe passed up through a rectangular cistern, nearly 163 inches in length and 96 in width, and

which consequently contained about fifty seven gallons on every inch in depth. For admitting the water, two holes were made in two opposite sides of the pipe, about ten inches high, with two sliders fitted to them, for occasionally varying their height and consequently the quantity of water received. On the outside of each hole was fixed an iron plate, perforated with numerous small holes, to keep back such matters as might choak up the throat: that the holes might be sufficient to allow water enough to pass in, the strainer was made wider than the aperture in the pipe, and bent to a semi-cylindrical form.

To the bottom of the funnel, enlarged as above mentioned, was fitted a pipe six feet high, and in width four inches by seven and a half. The lower end of this pipe was inserted into the head of a large cask without a bottom, which was set in a tub above three feet deep, with three supports under the lower edge of the cask to procure a space between it and the bottom of the tub for the water to pass freely off. About eight inches under the orifice of the pipe, a round board, for the water to fall on, was hung by three cords, which passed up through the head of the cask and were secured by pegs. At one side, a tin vessel full of water was supported in the same manner; and through a faucet, over the middle of this vessel, was inserted a glass tube thirty four inches long. At the other side was the blast pipe, about three quarters of an inch in diameter,

The machine being thus prepared, we proceeded to the trial of it, expecting that the two streams, from their sloping direction towards one another, would cross and be dashed into drops, and carry down abundance of air. But in the effect we were greatly disappointed: the blast was weak, and the gage rose to no considerable height, whether the wedge was dropt down or drawn up, so as to suffer the water to pass in less or greater quantity, in  
thin

thin or in thick sheets: in continued trials and variations of the apertures for three or four days, the gage was not once observed to rise so high as ten inches. A good deal of air indeed escaped through the junctures of the pipe and of the air vessel, but not near enough to make up the expected quantity.

The wedge answering so ill, it was laid aside; and in its place was introduced a leaden vessel, of the same shape with the funnel's throat, and of such a size, as to rest against the sides of the aperture by its upper edge, and hang six or seven inches down in the wider part of the pipe: in the sides and bottom of this vessel were made several holes, about two tenths of an inch in diameter. With this alteration I had the pleasure to find, that though air rushed out from the joints even more plentifully than before, yet the blast from the blowing pipe was strong, and the water in the gage pipe rose to the top and run over.

I tried to measure the quantity of water necessary for producing this effect for a certain time. The reservoir being filled to the depth of fourteen inches, the gage rose as before, and continued high for four minutes; after which it began to sink fast, the water in the reservoir having then become too low to keep the pipe full, though it continued to run for a considerable time longer. From the dimensions of the reservoir already mentioned it will appear, that if all the water had run out in the four minutes it would have amounted to near two hundred gallons in one minute; but at least a fourth of it remained after that period, so that the expence could not exceed a hundred and fifty gallons in a minute. We could not expect any great accuracy in this determination, because as the height of the water continually decreased in the reservoir, its velocity likewise decreased, so that if a due quantity.

quantity run in the last minute, a superfluous quantity must have run in the first.

The leaden cullender being taken out, and the whole throat left vacant for the stream, the gage still rose to the top; but the expence of water was now more than double to what it was before.

These trials, though not carried to such a length as I could have wished, satisfied me, and those who assisted at them, that much more air is to be obtained, by dividing the stream by means of a cullender, than by any other methods that have been tried; and that with such a machine as is above described, a stream of a hundred and fifty gallons at most in a minute is sufficient to produce a continued blast, from a pipe of three quarters of an inch bore, of such strength as to support a column of water of three feet or more.

To afford as much assistance as possible to those who may be desirous of erecting machines of this kind, I shall here collect into one view the most material particulars which my experiments have discovered with regard to the perfection of their structure, and form from them a description of such a machine as promises to be the most effectual.

The bottom of the reservoir of the water should be about fourteen feet above the level of the ground: we need not be very solicitous about procuring a greater height, for though a greater would be of some advantage, yet this advantage appears to be much less considerable than has been commonly imagined. In the channel by which the water is conveyed, are to be placed gratings of different sizes, as already mentioned, and before the aperture a finer grating, which may be either a perforated iron plate or a wire sieve, to serve as strainers for keeping back such matters as would obstruct the apertures  
which



which the water is afterwards to pass through. The stream should enter at one side, or be so managed, that the water in the reservoir or funnel may not be agitated by it, or put into a spiral motion, which our experiments have shewn to be very injurious.

In the bottom of the reservoir is to be made a round hole, for admitting the upper end of what we have hitherto called the funnel, but which may here be more conveniently a cylindrical pipe, of copper or of cast iron, five or six inches in the bore, and seven feet long. To the end of this pipe is to be fitted a cullender, about a foot long; with the holes triangular, of half an inch each side; and six or seven strips from top to bottom, at equal distances, preserved without holes, for admitting air to pass down to the lower streams. All the holes should be directed downwards, that the streams may not be forcibly projected against the sides of the pipe which is to receive them, so as to have their velocity too much diminished.

If there are six of the perforated spaces in the cullender, the number of holes in each may be twenty, so that the whole number will be one hundred and twenty. The side of each of the triangular holes being half an inch, the area of each will be the eighth part of a square inch, and the sum of their areas will be fifteen square inches. The quantity of water running through one aperture of such an area, at the depth of seven feet and a half under the surface, comes out on calculation about six hundred and twenty-two gallons in a minute; but the real quantity will doubtless be much less than this, on account of the great friction of the water in passing through a number of small holes, and of the resistance of the air, which increases in a very high ratio according to the increase of the velocity and enlargement of the surface: it is in part to make up for these retardations,  
that

that the pipe is directed to be made so high. The surface of the water is here above thirteen times greater than if it passed all through one circular aperture.

Both the pipe and the cullender should have a flanch or rim round their orifices, and be secured to one another by screws passing through the rims of both, with a plate of lead between them to make the juncture tight, as commonly practised in joining iron pipes for water works. This way of joining them admits the cullender to be taken off and cleaned, when a diminution of the effect of the machine shews the holes to be choked up, which however, it is apprehended, will seldom, if ever, happen.

As the holes will permit more water to run through, than may at all times be wanted, it is proper to have some contrivance for occasionally closing a part of them. This may be effected by means of a thin copper pipe, open at both ends, as high as the cullender, and of such width as just to drop into it. It will be easily conceived, that when this register is let entirely down, the lateral holes will be covered, and the water admitted only to those in the bottom; and that by raising it further and further, more and more of the lateral holes will be uncovered. The register is to be hung by a wire to a cross bar over the reservoir, by which it may be raised or lowered; and a scale or divided board may be adjusted against the upper part of the wire, for shewing the height of the register, or the number of holes closed by it.

The most commodious and effectual way of admitting air to the water appears to be that of our first experiments, viz. hanging the throat of the funnel, in this case the cullender, within the wider receiving pipe, for by this means the air is admitted freely and uniformly all round. This last pipe should likewise be of iron or copper, twelve inches

inches in diameter, and spread out at top to the width of sixteen or eighteen inches, that a large space may be left round the cullender : this space should reach three or four inches above the uppermost perforations of the cullender, to prevent any of the water from being dashed over the top.

A pit is to be sunk in the ground, not less than six feet deep. In this is to be placed an air vessel, made of wood lined with lead, without a bottom, three or four feet in width, and ten or eleven high. The vessel should be supported on feet, of a proper strength, with sufficient spaces between them for the water to pass freely out : this way is preferable to the common one of placing the lower edge of the vessel on the bottom of the pit, and cutting an aperture in the side, because the height of the aperture is so much taken off from that of the vessel. The reservoir being fourteen feet above the ground, and the upper pipe and cullender reaching down eight feet, only six feet remain below the cullender ; so that the air vessel, having six feet sunk in the ground, will reach nearly up to the cullender, and almost the whole height of the undermost pipe will be included within the vessel. This pipe may be above nine feet long, three feet or more of it going down into the pit ; which three feet are here an entire gain in the height of the fall, for the pipe in the other machines comes at most no lower than the level of the ground where the water runs off on the outside. This height is gained, in virtue of the compressed air in the vessel pushing down the water below, as already shewn in the second article of this section : it may be always as great as the height to which the water is intended to rise in the gage. At the distance of five or six inches under the orifice of the pipe is to be placed the concave iron plate or stone for the water to fall on. In the top of the air vessel is to be fixed the gage and the blowing pipe.

Such is the general construction of the blowing machine, which promises to be particularly useful in cases where water is scarce, or where the want of a natural fall renders it necessary to raise, by very expensive means, the great quantities requisite for working the common bellows. It is presumed, that one of these machines will be sufficient for the iron forge, and for foundry other purposes where the quantity of air is not required to be very great; that it will be less expensive, on account of the durability of its materials, and the simplicity of its structure, than any kind of bellows now in use; and what is of principal importance, that much less water will serve for working it. In cases where one of the machines cannot supply air enough, as for the large iron smelting furnace, two pipes may be used, both fed by one reservoir, and entering into one air vessel, as practised in some of the instruments described in the first section. The using of two pipes appears more eligible than enlarging the bore of one; for air cannot be so freely introduced into a large body of water, though divided into streams by the cullender, as into two smaller ones of equal quantity.

It may be observed, that the blast will be stronger in a dense state of the atmosphere, than when it is more rare or expanded, a greater quantity of air being then introduced under an equal volume. If therefore the quantity of water has been adjusted so as to raise the gage to a proper height when the air was light, it will frequently happen that the same quantity of water shall raise it higher, and consequently, if no greater height is required, that a part of the water may be saved. As the gage of our machine discovers by inspection these variations in its effect, the register affords convenient means of regulating its power, and increasing or diminishing the quantity of water.

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## VI. HISTORY OF COLOURS.

### PART I.

#### *Of Black.*

**B**LACK, a colour in many cases the most important, and in its use the most extensive, of all those which art is concerned in preparing or applying, is chosen as the first article of an experimental history of colours; which will be occasionally continued in the prosecution of this undertaking.

The practices of the workmen in one branch of colouring are generally little known to those who are employed in another; the several methods of applying even one colour, on different kinds of bodies, being the objects of so many distinct arts, each of which has its own rules of working, peculiar to itself, and established by long custom.

Of the arts of communicating a black colour to different subjects, there are some which have made great advances towards perfection, whilst others remain far more imperfect, in regard not only to the dispatch and facility of the execution, but likewise to the beauty and duration of the colour. Thus woollen and silk are both dyed of a permanent deep black, but with this difference, that what the woollen dyer effects by three or four dippings of the cloth in his dying liquor, the silk dyer scarcely obtains from twenty or thirty dips; whereas, on the contrary, the dyer of linen and cotton thread, however he prolongs the operation, or repeats the dippings, is unable to communicate to the thread a blackness that shall endure wearing. Thus also the printer fixes upon paper an ink which con-

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tinues unaltered for ages, and which is not perhaps capable of being changed by any natural agent that the paper itself can resist; while the common writing inks soon lose of their colour both on paper and on parchment, in so much that records, of no very long standing, have become almost entirely obliterated.

In the present history, I shall endeavour to trace, as far as my opportunities of information will enable me, the preparation, production, and communication of black colours, through all the professions in which they are concerned; that the artist, confined by his employment to particular views, may be made acquainted with the methods, by which similar effects to those which he produces, or wants to produce, are obtained in other arts, or in arts which in other respects differ from his own. Experiments, while they serve as a sure test for ascertaining the respective facts, will often contribute at the same time to enlarge and render them more extensive; and likewise afford means of distinguishing, in some complex operations, the circumstances or materials essential to success, from the superfluous or injurious ones, which ignorance or chance perhaps at first introduced, and which prejudice or custom have continued.

By thus examining and comparing the different methods, by which a similar colour is obtained or produced, and by which the several tinging materials are applied on different subjects, I flatter myself that many of these arts, however disjointed among different sets of workmen, will be found to have natural and strong connections, so that an effective and useful commerce may be established among them; that they will not only tend to illustrate, but mutually to improve one another; and that in many cases the practice of one art may be abridged or facilitated, its imperfections remedied, and its deficiencies supplied, by  
means.

means, which could scarcely ever be thought of by a person conversant in that art singly, but which a general knowledge of the others may be expected to suggest.

## S E C T. I.

*General observations on black colours.*

**O**F black, as of other colours, there are many shades or varieties; different bodies, truly and simply black, or which have no sensible admixture of any of the rest of the colours, as black velvet, fine black cloth, the feathers of the raven, &c. appearing, when placed together, of tints very sensibly different.

2. One and the same body also assumes different degrees of blackness, according to the disposition of the sensible parts of its surface; and in this respect, there is not, perhaps, any other colour, which is so much affected by an apparent mechanism. Thus black velvet, when the pile is raised, appears intensely black, much more so than the silk it was made from; but on pressing the pile smooth, it looks pale, and, in certain positions, shews somewhat even of a whitish cast.

3. This observation is agreeable to the physical theory, which ascribes the blackness of bodies to the luminous rays, that fall upon them, being in great part absorbed, or stifled in their pores. When the surface is composed of a multitude of loose filaments, or small points, with the extremities turned towards the eye, much of the light is stifled in the interstices between them, and the body appears dark: when the filaments are pressed close, or the surface smoothed and polished, more of the light is reflected from it, and the intensity of the blackness is diminished; though the beauty may be improved by the glossiness which results from the smoothing.

4. There is one case however, in which a high poliffi may, on the same principle, produce blackness, in bodies otherwise even white. We find that specula of white metal or of quicksilvered glass, which reflect the rays of light to one point or in one direction, look always dark, unless when the eye is directly opposed to the reflected rays.

5. As the absorption of the luminous rays, except in the case just mentioned, makes the physical cause of blackness; it is concluded that black bodies receive heat more freely than others. Black marble or tiles, exposed to the sun, become sensibly hotter than white ones. Black paper is kindled by a burning-glass much sooner than white, and the difference is strongly marked: a burning-glass, too weak to have any visible effect at all upon white paper, shall readily kindle the same paper rubbed over with ink. Hence black clothes, when wetted, are said to dry faster; black habits, and rooms hung with black, to be warmer; black mould to be a hotter soil for vegetables; and garden walls, painted black, to answer better for the ripening of wall fruit; than those of lighter colours.

6. It is not however to be affirmed that the like differences obtain in the impressions made by common fire. Black paper, held to the fire, does not seem to be affected sooner, or in a greater degree, than such as is white. It may be proper to observe also, that the combustibility of the paper may be increased, by impregnating it with substances of themselves not combustible, and which give no colour to it. This is the foundation of one of the sympathetic inks, as they are called, made of a strong solution of sal ammoniac in water, which, though colourless when written with on paper, becomes very legible on exposing the paper to the fire; that is, it occasions the parts moistened with it to scorch or burn, before the rest of the paper is hurt, to a brown or black. All the salts I have tried  
produced



produced this effect in a greater or less degree ; nitre, alum, tartar, very weakly ; sea salt more strongly ; fixed alkaline salts still more so ; sal ammoniac the most strongly of all. Metallic solutions, made in acids, and diluted so as not to corrode the paper, acted in the same manner.

7. Besides the simple blacks, there are a multitude of compound ones, inclining more or less to other colours. Thus the painters have blue-blacks, brown-blacks, &c. which may be made by mixing pigments of the respective colours with simple black ones, in greater or less quantity, according to the shade required. The dyers also have different blacks, and often darken other colours by slightly passing them through the black dying liquor ; but the term brown-black is in this business unknown, brown and black being here looked upon as opposite to one another. In effect, the colour called brown-black is no other than that which ill dyed black clothes change to in wearing : no wonder then that it is excluded from the catalogue of the dyers colours.

8. The true or simple blacks, mixed with white, form different shades of grey, lighter or darker according as the white or black ingredient prevails in the mixt. The black pigments, spread thin upon a white ground, have a like effect.

9. Hence the painter, with one true black pigment, can produce on white paper, or on other white bodies, all the shades of grey and black, from the slightest discoloration of the paper, up to a full black : and the dyer produces the same effect on white wool, silk, or cloth, by continuing the subjects for a shorter or longer time in the black bath, or making the bath itself weaker or stronger.

10. Hence also the dilution of black pigments with white, or the spreading of them thin upon a white ground, affords a ready method of judging of the quality or species  
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of the colour; which, if it be a true black, will in this diluted state look of a pure or simple grey, but if it has a tendency to any other colour, that colour will now betray itself.

11. All the colours, in a very deep or concentrated state, approach to blackness. Thus the red liquor prepared by boiling or infusing madder root in water, and the yellow decoction or infusion of liquorice root, evaporated in a gentle heat till they become thick, look of a dark black colour, or of a colour approaching to blackness; and these thick masses, drawn out into slender strings, or diluted with water, or rubbed on paper, exhibit again the red and yellow colours, which the liquors had at first. Nature affords many black objects, whose blackness depends upon the same principle, being truly a concentration of some of the other colours. Thus in black cherries, currants, elderberries, &c. what seems to be black is no other than an opaque deep red: their juice appears black when its surface is looked down upon in an opaque vessel, but red when diluted or spread thin. The black flint, as it is called, of the island of Ascension, held in thin pieces between the eye and the light, appears greenish; and one of the deep black stones called black agate, viewed in the same manner, discovers its true colour to be a deep red.

## S E C T. II.

### *Native black colours.*

**T**H E mineral kingdom affords abundance of bodies uniformly tintured or variegated with black, or with a deep colour approaching to blackness: Such are, the black flates, which make an ornamental covering for houses: the black touchstone, on which pieces of metals being rubbed leave a mark of their own colour; which shews the  
colour

colour the more perfectly by virtue of its blackness, and which thus enables us to judge and compare the colour and fineness of metallic compositions, with much more certainty than could be done by viewing them in the mass: the black flint so called, which performs the same office with the touchstone, and being harder than the common touchstones, answers better for the hard metals: the common black marbles, used for many kinds of ornamental works: the more rare black marble, called *lapis obsidianus* or *opfianus*, which, in virtue of the very high polish it receives, was made into mirrors by the Greeks and Romans: the black gallinazo stone, described by D'Ulloa, which answered the same purposes among the Indians of Peru before the conquest of that kingdom by the Spaniards: the black jet, and other substances of the same class, which are formed into many elegant toys: the plain and variegated black agates, pebbles, crystals, &c. which are cut by the jeweller. The stone called tourmalin, remarkable for the singular phenomena it exhibits in some electrical experiments, is in its rough state of a full black colour, though when polished it looks rather of a brown black: I have been informed by a skilful jeweller that he had seen a black diamond, cut and set in a ring; though perhaps the examination made of it was not so rigorous as could be wished for determining its being truly of the diamond kind. However this may be, a black tinge in bodies of this class is looked upon as an imperfection or foulness, although, when the diamond is cut, a black foil placed under it improves its beauty: for the rose diamonds, the collet, or socket in which the stone is set, is specked with ivory black in little dots; and for brilliants it is all over blacked.

Among vegetables and animals, blackness, though frequent, is less diffused, or of more limited extent. The black colour of the stalks and seeds of certain plants, that  
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of shells, feathers, and hair, and that of the skin of the human species in certain climates, is only a superficial teint. The blackness of fruits, as already observed, is generally rather a concentration of some other colour than a true black. Some woods, particularly the ebony, are tinged throughout with a true blackness, on which great part of their value depends, and which art very happily imitates on more common woods. The bony matter which lines the mouth of certain whales has likewise frequently a pretty deep black tincture, joined to another quality, elasticity, on many occasions more important than its colour.

Among the various substances which nature has impregnated with a deep and permanent black colour, there are few of which art can avail itself for communicating this colour to other bodies. There is not perhaps any instance of a black colour being, as the rest of the colours frequently are, extracted from one body by means of dissolvents, and thence introduced into another. Nor can the generality of natural blacks be applied in their whole substance; some of these bodies being of such a texture, as does not admit of their being reduced into sufficiently fine powder, for being mixed with a proper cementitious matter, so as to be spread smooth; and others having their colour destroyed by the pulverization. Of these last we see an instance in the common black slates, which may be scraped into a white dust, in which the slightest scratches look white, and which, when drawn along any other black body, as hard as themselves and not polished, leave a white mark; a property which, while it renders them utterly unfit for any purposes in painting or staining, is that on which their use depends for occasional writing, or for making pencils for writing on other stones. It is obvious, that for this intention, black stones are better adapted than those

those of any other colour; and that the stone should be somewhat harder than the pencil, that the marks may proceed chiefly from the pencil, without scratching the substance of the stone.

The only native blacks I know of, that have been employed as colouring materials, are the following.

### I. *Black chalk.*

THE black chalk or black marking-stone of the shops, so called from its use in drawing black lines on paper, is a light earthy substance, of a pretty deep black colour, moderately firm, in texture somewhat flaky like slate, not of a rough harsh surface like common chalk, but rather soft and smooth to the touch. It stains very freely, and, in virtue of its smoothness, makes very neat marks. It is easily reduced into an impalpable soft powder, without any apparent diminution of its blackness. In this state, it mixes easily with oil into a smooth paste; and being diffused through water, it slowly settles, in a black slimy or muddy form; properties which make its use very convenient to the painter both in oil and water colours. Entire masses of it, laid in water, are also by degrees penetrated and disunited, though much more difficultly than those of white chalk.

It appears, in effect, to be an earth of a quite different nature from common chalk, and seems to be rather of the stony bituminous kind. In the fire it becomes white with a reddish cast, and very friable; retaining its flaky structure, and looking much like the white flaky masses which some sorts of piteal leave in burning. Acid liquors neither dissolve, nor alter the colour of the black chalk itself; nor have they, so far as I could observe, any sensible action upon the white ashes.

Our colour shops are said to be supplied with this useful earth from Italy and Germany; though some parts of England afford substances, nearly, if not entirely, of the same quality, and which are found to be equally serviceable, both for marking and as black paints. Such particularly is the black earthy substance called Killow; said by Dr. Merrett, in his *Pinax rerum Britannicarum*, to be found in Lancashire; and by Mr. Da Costa, in his history of fossils, to be plentiful on the side, near the top, of Cay-Avon, an high hill in Merionethshire. The killow has somewhat of a bluish or purplish cast mixed with its blackness, as the black chalk likewise has: hence it is named by Merrett blue marking stone, *lapis cæruleus killow dictus ducendis lineis idoneus*. There is a harder and softer kind of it, *killoia duriuscula et molliuscula* of Woodward's method of fossils.

## II. Pitcoal.

FROM the deep glossy black colour of some of the common sorts of pitcoal, I was induced to make trial of them as paints: their affinity to oils, in virtue of their bituminous nature, promised also some advantages, in oil painting, above the substances of a more earthy kind. Several of the finer pieces, levigated into an impalpable powder, were mixed both with oil and with gum water, and applied on paper and on wood. Both mixtures, when laid on thick, appeared of a pretty good black colour, though much inferior to that of the coal at first; and the oily one seemed to dry sooner than oil paints generally do. Laid on thin, or in a dilute state, they looked brown, not of the grey colour which results from the dilution of a pure black. Pitcoal therefore may be considered, not as a true black, but as a brown-black; a colour on many occasions wanted in painting, and which, as I have been informed by an ingenious

genious artist, is often in business produced with this material.

As different sorts of pitcoal, and different pieces from one pit, differ much from one another in degree and species of colour, some care should be taken in the choice of them, according to the purpose they are intended for. All the sorts, at least all which I have tried, require long grinding in order to their being reduced into a powder of sufficient fineness.

### III. *Black sands.*

THE black sands, one of the brightest and most beautiful of which is found in Virginia, lose their colour on being ground into powder, and hence cannot be used as pigments. There are however cases, in which they may contribute to the embellishment of certain works, by being strewed upon oil paintings for a sparkling black, in the same manner as smalt is strewed for blue. In this intention they are used on writings, preferably to the white sands, as they do not weaken the colour of the ink, but coincide with its blackness, and give an agreeable lustre.

### IV. *Black-lead.*

THIS mineral is dug in our own country; and is here, as Dr. Woodward observes, in the preface to his method of fossils, more plentiful, and of a better kind, than in any other part of the world. According to Dr. Plott's account, in the Philosophical Transactions, No. 240, it is found only at Keswyc, in Cumberland, and is there called *wadt* or *kellow*, by which last name, as we have already taken notice, an earth like the black chalk is distinguished in other places.

The colour of black-lead, rather a deep shining bluish grey than a black, may be seen, diluted a little, in the black

melting pots when broken or the surface scraped off, and entire in the genuine sort of black pencils. It differs not a little in goodness, some sorts marking paper freely, and others very difficultly or scarce at all. It is smooth and as it were unctuous to the touch, and hence is sometimes used instead of oil or soap, for giving slipperiness to the rubbing parts of machines. Acids neither dissolve it, nor alter its colour or unctuousity.

Black-lead has not been found to contain any of the metal from which it receives its name, and its composition appears to be of a very singular kind. From its known resistance to vehement degrees of fire, whether urged by itself in close vessels, or made with clay into melting-pots and placed among the burning fuel, it should seem that it could not partake largely of any volatile substance; and it has been generally supposed to consist chiefly of a talky earth. But Mr. Quist relates, in a curious paper of experiments on black-lead, published in the Swedish transactions for 1754, that having exposed many different specimens of this mineral to a strong heat, on a scorifying dish under a muffle, they all yielded sulphureous fumes and flowers in great abundance; and that there remained behind, from one sort, only a fifth part of its weight, and from another no more than a twentieth part, of a yellow or brown calx, which being treated with inflammable fluxes, yielded seven tenths its weight of a metallic mass, which seemed to be a mixture of iron and tin. Agreeably to these experiments, in an essay for a new system of mineralogy, published lately in Sweden, ascribed to the celebrated Mr. Cronstedt, and which bears strong marks of great knowledge and experience in the mineral kingdom, black-lead is classed among the sulphureous minerals, and called *sulphur satiated with iron and tin*.

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I could not persuade myself that the minerals, on which the above experiments were made, could be such as are called among us black-lead, till some of the finest black-lead of our pencil-makers, weighing one hundred and sixty-eight grains, in three pieces, having been kept of a moderately strong red heat on a scorifying dish for three hours, with the common precaution of covering the vessel for a time, lest the matter should crackle, and some particles be thrown off from it in substance; I found it reduced to about an hundred and twenty grains, and all the pieces changed on the outside to a sparkling rusty brown calx, of which a considerable part was attracted by a magnetic bar, the internal parts continuing of the same appearance as at first. Being then broken into smaller pieces, and exposed to a like heat for two hours, it suffered the same change as before, and was reduced to about sixty grains. Being further broken, and calcined with a moderate red heat for ten hours, it was diminished to thirty grains; and by a repetition of this operation, to twelve grains, or a fourteenth part of its first weight.

The remarkable dissipation, in these experiments, of a substance which in close vessels resists intense fires, may be somewhat illustrated by the known property of charcoal, which when excluded from the action of the air, whether by being inclosed in a vessel, or mixed with clay into a mass, remains unconsumed and unaltered in the fire. Masses of black-lead seem to calcine and suffer a dissipation only on the surface; the internal part remaining long unchanged, unless the mass be broken, or the calx rubbed off, so as that fresh surfaces may be exposed to the air. The common black-lead melting-pots, made of clay and the coarser kinds of black-lead powdered, like those made of clay and charcoal powder, lose their external blackness with part of their weight, and thus have their staining quality

quality destroyed, by strong fire. Hence furnaces made of these pots, as described at the beginning of this volume, after they have suffered strong fire, cease to discolour the hands.

Black-lead in fine powder, stirred into melted sulphur, unites with it so uniformly, and in such quantity, in virtue perhaps of its own abounding with sulphur, that though the compound remains fluid enough to be poured into moulds, it looks nearly like the coarser sorts of black-lead itself. Probably the way which prince Rupert is said to have had, mentioned in the third volume of Dr. Birch's History of the Royal Society, of making black-lead run like a metal in a mould, so as to serve for black-lead again, consisted in mixing with it sulphur or fulphureous bodies.

On this principle the German black-lead pencils are said to be made; and many of those which are hawked about by certain persons among us, are prepared in the same manner: their melting or softening, when held in a candle, or applied to a red hot iron, and yielding a bluish flame, with a strong smell like that of burning brimstone, betrays their composition; for black-lead itself yields no smell or fume, and suffers no apparent alteration, in that heat. Pencils made with such additions are of a very bad kind: they are hard, brittle, and do not cast or make a mark freely either on paper or wood, rather cutting or scratching them than leaving a coloured stroke.

The true English pencils (which Vogel in his Mineral System, and some other foreign writers, imagine to be prepared also by melting the black-lead with some additional substances, and casting it into a mould) are formed of black-lead alone, sawed into slips, which are fitted into a groove made in a piece of wood, and another slip of wood glued over them: the softest wood, as cedar, is made choice of, that the pencil may be the easier cut; and a  
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part at one end, too short to be conveniently used after the rest has been worn and cut away, is left unfilled with the black-lead, that there may be no waste of so valuable a commodity. These pencils are greatly preferable to the others, though seldom so perfect as could be wished, being accompanied with some degree of the same inconveniences, and being very unequal in their quality, on account of different sorts of the mineral being fraudulently joined together in one pencil, the fore part being commonly pretty good, and the rest of an inferior kind. Some, to avoid these imperfections, take the finer pieces of black-lead itself, which they saw into slips, and fix for use in port-crayons: this is doubtless the surest way of obtaining black-lead crayons, whose goodness can be depended on.

#### V. *Black vegetable Juices.*

THE excellent black varnish of China and Japan, which has hitherto been but imperfectly imitated in Europe, and which was formerly thought to be an artificial composition of resinous bodies coloured with black pigments, has been discovered, by the later travellers in those countries, to be a native juice, exuding from incisions made in the trunks of certain trees. One of these trees, according to the account given of it in Kämpfer's *Amanitates exoticæ*, is that whose fruit is sometimes brought to Europe, as a medicinal drug, under the name of anacardium.

The anacardium itself, as it comes to us, is remarkable for a black-colouring juice. It is a kind of nut, with a double shell, containing, in the space between the outer and the inner shell, a fungous substance filled with a dark-coloured viscous fluid, which is easily forced out, by cutting the nut, and squeezing it between the fingers: a little warmth, by liquefying the thick matter, makes it come out more freely; though the quantity obtained, either with or without heat, is not very considerable. This juice, rubbed

bed on linen or cotton, gives a reddish-brown stain, which soon deepens in the air to a black, and which I have not found to be discharged by washing, and boiling, with soap or alkaline ley. Hence the anacardium is said to be used for marking linen and cotton cloths, and to be known all over India by the name of marking nut.

The cashew nut, called by some the anacardium of the West-Indies, and which in several respects has a great resemblance to the oriental anacardium, differs from it in its colouring quality; the juice lodged between its shells being much paler, and giving to linen, cotton, or paper, only a brownish stain, durable indeed, but which does not change at all towards blackness.

There are however trees, natives of our own American colonies, which appear to contain juices of the same nature with the valuable productions of the Indian. Of this kind are several, and perhaps the greater number, of the species of toxicodendron or poison-tree. Mr. Catesby, in his history of Carolina, describes one, called there the poison-ash, from whose trunk flows a liquid, black as ink, and supposed to be poisonous: this reputed poisonous quality, as I have been informed by some gentlemen of that country, has hitherto deterred the inhabitants from attempting to collect or make any use of it. The abbé Mazéas, in the *Philosophical Transactions*, vol. 49, for the year 1755, gives an account of three sorts of the toxicodendron, raised in a botanic garden in France, containing in their leaves a milky juice, which in drying became of a deep black, and communicated the same colour to the linen it was dropt on: the linen, thus stained, was boiled with soap, and came out without the least diminution of its colour; nor did strong ley of wood-ashes make any change in it.

Several of these trees have been raised in the open ground in England: some of them still remain in the  
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bishop of London's garden at Fulham, after having been long neglected, and suffered many severe winters: see a catalogue of the exotic trees in this garden, by Dr. Watson, in the Philosophical Transactions, vol. 47, for the years 1751 and 1752. They appear also to perfect their colouring juices, in this, nearly as well as in their native climate. The species called by Mr. Miller the true lac tree, of which I was favoured with a branch by himself from Chelsea garden, was found to contain, in its bark, and in the pedicles and ribs of the leaves, a somewhat milky juice, which soon changed in the air to a reddish-brown, and in two or three hours to a deep blackish or brownish-black colour: wherever the bark was cut or wounded, the incision became blackish; and on several parts of the leaves the juice had spontaneously exuded, and stained them of the same colour. This juice, dropt on linen, gave at first little or no colour, looking only like a spot of oil; but by degrees the part moistened with it darkened in the same manner as the juice itself. On washing and boiling the linen with soap, the stain not only was not discharged, but seemed to have its blackness rather improved; as if a brown matter, with which the black was manifestly debased, had been in part washed out, so as to leave the black more pure.

It were to be wished that some attempts were made, for collecting the colouring juices of these trees, in sufficient plenty, for answering the important purposes to which they promise to be applicable. Perhaps also means might be found of introducing into some parts of the extensive dominions of Great-Britain, in which all varieties of soil and climate are now to be met with, the oriental trees themselves, to which some of the Indian manufactures are supposed to owe distinguished advantages. This there are now some grounds to hope for, from the patronage of a

society, whose encouragement has already so greatly promoted the culture of many valuable plants and trees.

As the milky juices of some of our common plants turn dark-coloured or blackish in drying, I was induced to make trial of several of them on linen: The milks of wild poppies, garden poppies, dandelion, hawkweed, fowthistle, gave brown or brownish-red stains, which were discharged by washing with soap: the milks of the fig-tree, of lettuces, and of different kinds of spurges, gave no colour at all. The colourless juice which issues from hop-stalks when cut, stains linen of a pale reddish or brownish-red, extremely durable: I tried to deepen the colour by repeated applications of the juice, but could never make any approach to blackness. The juice of floes gave likewise a pale brownish stain, which, by repeated washings with soap, and wetting with strong solution of alkaline salt, was darkened to a deeper brown: on baking the floes, their juice turns red, and the red stain which it then imparts to linen is, on washing with soap, changed to a pale bluish, which also proves durable. The juices both of the raw and baked floes were applied repeatedly on the same spots, in order to deepen the respective colours; and the brown or reddish-brown stain of the raw floe, and the blue of the baked, were applied on one another, on principles hereafter explained. In all these ways a stain was obtained, which when slightly washed with soap, looked of a pretty deep black; but by longer washing, much of the colour was discharged, and little more was left than a single application of the juice would have produced. The floes were tried in different states of maturity, from the beginning of september to the middle of december; and the event was always nearly the same. Though these experiments, with many others of the same kind, proved unsuccessful in regard to the production of the colour here intended,

ded, they serve to point out means, which may be convenient and useful on some occasions, of marking linen with a colour, pale indeed, but sufficiently visible, which soap does not discharge.

In the fifth volume of the celebrated Linnæus's *Amœnitates academicæ*, mention is made of a black colour obtained from the berries of two plants, which grow wild in some of the northern parts of England, and which I have not hitherto had an opportunity of trying. One is the *actæa spicata* or *christophoriana*, herb-christopher or bane-berries; the other *empetrum procumbens* or *erica baccifera nigra*, black-berried heath, crow-berries, or crake-berries. The juice of the bane-berries, boiled with alum, is said to yield a black ink; and the heath-berries, boiled also with alum, to dye cloths of a purple-black.

#### VI. Cuttle fish ink.

THE cuttle fish, said to be pretty common in the Mediterranean, is not wholly a stranger to our own seas, as appears from its bone found on our shores. This bone is hard on one side, but soft and yielding on the other, so as readily to receive pretty neat impressions from medals, &c. and afterwards to serve as a mould for the casting of metals, which thus take the figure of the original: the bone is frequently employed likewise for polishing or cleaning silver. Mr. Borlase, in his natural history of Cornwall, says that these bones, whose characters are so obvious and so singular that they cannot be mistaken, are found frequently on the shores of Mounts bay; and likewise gives a description of the fish itself as caught there on the sands in 1756. Dr. Leigh also, in his natural history of Lancashire and Cheshire, relates that he has seen the fish several times on the shores of those counties.

This fish contains, in a certain distinct vessel, a fluid as black as ink : which it is said to shed on being pursued, and thus to conceal itself by discolouring the water. The particular qualities of this black animal liquor I have had no opportunity of examining myself, nor have I been able to obtain any satisfactory information concerning them from others. Dr. Leigh, in the place before referred to, says he saw a letter, which had been written with it ten years before, and which still continued : it were to be wished he had specified more particularly the continuance of the colour, whether in its full deepness, or much faded. Some report that the ancients made their ink from it, and others that it is the basis of the Indian or China ink : both these accounts appear however, from some experiments and observations which will be related in the sequel of this essay, to have little foundation : Pliny, speaking of the inks used in his time, after observing that the cuttle fish is in this respect of a wonderful nature, adds expressly that ink was not made from it.

### S E C T. III.

#### *Black produced by Fire.*

**T**HE action of fire properly applied, in the burning of animal and vegetable substances, produces, in the coal and in the foot, the two most durable and useful blacks of the painter and the varnish-maker. The coal in particular is of extreme permanence, resisting the force of time, and all the known agents of nature, except only that of an open fire, which burns it into white ashes. Some bodies of the metallic kind assume also, in certain circumstances, a black colour from fire.

#### I. *Char-*



I. *Charcoal Blacks.*

MOST of the blacks of this class, besides their incorruptibility, have the advantage of a full colour, and work freely in all the forms in which powdery pigments are applied; provided they have been carefully prepared, by thoroughly burning the subject in a close vessel, and afterwards grinding the coal into a powder of due fineness.

Pieces of charcoal are used also in their entire state, for tracing the outlines of drawings, &c. in which intention they have an excellence, that their mark is easily wiped out. For these purposes, either the finer pieces of common charcoal are picked out and cut to a proper shape; or the pencils are formed of wood, and afterwards burnt into charcoal, in a crucible, or other like vessel, covered and luted. When the process is skilfully managed, the coal retains exactly the figure of the wood: some have been so dextrous as to char an arrow, without altering the form even of the feather.

The artists commonly make choice of the smaller branches of the tree, freed from the bark and the pith; and some particular kinds of wood, as the willow and the vine, they generally prefer to others. To discover the foundation of this preference, and how far the coals of different vegetables differ from one another as colouring materials, I made the following experiments.

Small branches of the willow, vine, cherry, apple, pear, peach, plum, fig, birch, oak, elder, alder, yew, floc, hazel, fir and pine trees, were thoroughly dried, and inclosed in a mass of luting, made of clay beaten up with sand and horse-dung: the mass, dried slowly and gradually heated to prevent its cracking, was kept red hot about three hours. On carefully breaking it, the pieces were all found well charred; but it could not be observed

served that they differed greatly from one another, either in degree of colour, or in the freedom of their marking upon paper.

This experiment affording little decisive, I repeated the opération in crucibles, with greater quantities of the materials, that a more exact comparison might be made of the colour of the coals, by using them as paints, both in a concentrated and diluted state. Two crucibles were filled with vine twigs, cut in small bits, freed from the knots, and thoroughly dried: the mouth of one crucible being then fitted into that of the other, the juncture was well secured with luting. Small smooth branches of most of the other kinds of trees above mentioned, were in like manner inclosed, each in two crucibles, and all of them continued about four hours in a strong red heat. Cuttings of white paper, beaten with water into a paste, such as is called *papier maché*, that they might take up less room in the crucibles, and have less air lodged in their interstices, were dried and treated in the same manner; but some flame appearing to burst out through a small crack which the vapour had forced in the luting, it was necessary to take out these crucibles after they had been about ten minutes in a red heat: the paper, nevertheless, was perfectly charred.

The several coals were levigated into fine powder, mixed both with gum water and oil, and applied as paints, both thin and thick, by themselves, and diluted with different proportions of white. All of them, when laid on thick, appeared of a strong full black; it could not be judged that one was of a finer colour than another. When spread thin or diluted, there were indeed some sensible differences among them, but neither very considerable, nor of such a kind as to be easily expressed or described: they had all somewhat of a bluish cast, but different persons,

sons, to whom the comparisons were referred, differed in their judgements of them, and could not fix on any particular coals as being more bluish, more truly black, or more beautiful than the rest.

Instead of the small branches, I tried next pieces of different woods, taken from the trunks of the trees. Here also the several coals appeared alike among themselves, and scarcely differed in point of colour from those of the twigs; but they seemed in general somewhat harder, and did not mark quite so freely on paper when used as crayons. Suspecting from hence that the hardness of the coal might be proportional to that of the subject it was prepared from, I made some further trials, which seemed to confirm this notion. The coals of the hard woods, box and guaiacum, were very sensibly harder than those of the soft ones: the shells and stones of fruits yielded coals still harder, which would scarcely make any mark on paper at all; while the coals of the kernels of fruits were quite soft and mellow.

It may be judged from these experiments, that the preference of one kind of wood to another for making charcoal crayons, does not depend so much upon any difference of colour in the coals, as on their softness; in which quality perhaps none of our common woods is equal to the willow. Dr. Grew observes, in his anatomy of plants, that in this wood the softness is equal or alike in all parts; whence the coal, when used as a crayon in painting, not only makes the stroke light, but every where certain, without disturbing the even motion of the hand. Deal or fir is likewise a very soft wood, but of unequal softness, so that when cut across, it tears, and will never polish or work smooth, whereas the willow works well in all directions.

Horns,

Horns, and the bones both of fishes and of land animals, gave coals rather glossier and deeper coloured than the vegetable coals, and which in general were very hard, so as difficultly or not at all to stain paper. It seemed here, as in vegetables, that the hardness of the coal depends on that of the subject matter; for silk, woollen, leather, blood, and the fleshy parts of animals, yielded soft coals. Some of these coals differed from others very sensibly in degree of colour: that of ivory is superior to the rest, and is indisputably the finest of all the charcoal blacks. Indeed we have no black pigments equal in beauty to ivory black, genuinely prepared, but some care is requisite in the choice of it, what is generally sold under this name being no other than the coal of common bones.

On comparing the vegetable and animal coals together, in their lighter shades, on paper, the bluish cast, observed in all those of the vegetable kingdom, was much less conspicuous in those of the animal, many of which seemed to incline rather to brown than to blue. In the colour-thops a preparation is sold under the name of blue-black, which in this respect differs from the animal and agrees with the vegetable coals, seeming to have no greater a degree of blueness than the coals of the woods and twigs above-mentioned, and even than common charcoal. That this preparation is no other than a vegetable coal, appeared from the following experiment. Laid on a red-hot iron, it burnt and glowed like powdered charcoal, and turned into white ashes; which ashes, thrown into oil of vitriol diluted with water, very readily dissolved into a bitterish liquor, the characteristic by which the vegetable earth is distinguished. From what particular vegetable matter this blue-black is prepared, experiments cannot discover; but those already mentioned seem sufficient to shew, that it may be obtained from many, and that

that the choice of the vegetable subject affects rather the softness or hardness than the colour of the coal.

After examining the different substances of the vegetable and animal kingdoms, I tried a mineral body, pitcoal; of which several pieces, of different sorts, were charred in close crucibles. The charred coals, reduced into fine powder and used as paints on paper, shewed nothing of the brownish hue which the unburnt pitcoal had when tried in the same manner, all of them inclining to bluish, and most of them having this cast in a greater degree than any of the vegetable coals. The blue-black of the shops cannot however be of this origin, the ashes of the charred pitcoal not being dissoluble by the vitriolic acid, as those of the blue-black were found to be.

## II. *Soot blacks.*

THE soot blacks are in general much softer and of a more yielding texture than those of the charcoal kind, and require much less grinding for uniting them with oily, watery or spirituous liquors, into a smooth mass: of some of them a part is dissolved by water or spirit of wine, while none of the charcoal blacks have been found to contain any thing dissoluble.

This soluble matter of soot is not however black like the indissoluble parts; and in this particular, as well as in the colour of the entire mass, different sorts of soot differ from one another. Thus the soot of pitcoal collected in common chimneys, of itself rather greyish-black than of a full black, being infused separately in rectified spirit of wine and in water, tinged the former of a transparent reddish colour, and the latter of a paler reddish; while the deeper black soot of wood, both to spirit and to water, gave an opaque dark brown.

From the watery infusion of wood foot is prepared the brown pigment called bistre, for painting in water colours. According to Mr. Landois, in the French *encyclopedie*, the foot is either boiled in water, or ground with a little urine (water will do as well) into a smooth paste, and then diluted with more water: after standing for about half an hour, till the grosser substance of the foot has settled, the liquor is poured off into another vessel, and set by for two or three days, that the finer parts may fall to the bottom, which fine matter is the bistre. That the bistre of our colour shops has been prepared by a process of this kind, and not, as some have suspected, by evaporating the infusion of foot to an extract, may be presumed both from its appearance and its qualities. It is in little masses, such as are obtained in the common way of drying precipitates, or earthy powders that have been ground with water, by dropping them on a chalk stone. It readily mingles with water, and continues for a time uniformly diffused through the fluid: a considerable part was observed to settle in an hour or two, a part more slowly, and after standing for many weeks a part remained dissolved in the water, so as to tinge it of a brownish-yellow colour, like a weak infusion of foot: this tinged liquor passed through a filter, without any separation of the colouring matter. In the preparation of the bistre, when the foot liquor has deposited all that will settle, the sediment, however drained, will necessarily retain some of the coloured fluid, which, drying, will leave in it some of the truly dissoluble parts of the foot; and hence probably proceeds the matter in bistre which we find to continue dissolved in water, the proportion of which is inconsiderable, compared to that which precipitates. Different parcels of bistre differ considerably in their colour, on account, probably, of the different qualities of the foots which they were made from.

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The finest of the foot blacks, and the only one commonly made use of as a black pigment, is that called lamp-black, which is brought chiefly from Germany and Sweden. Its preparation is described in the Swedish transactions for the year 1754, as a process dependent on the making of common resin: the impure resinous juice, collected from incisions made in pines and fir trees, is boiled down, with a little water, and strained, whilst hot, through a bag: the dregs and pieces of bark, left in the strainer, are burnt in a low oven, from which the smoke is conveyed, through a long passage, into a square chamber, having an opening in the top, on which is fastened a large sack, made of fleasy or thin-woven woollen stuff: the foot, or lamp-black, concretes partly in the chamber, from which it is swept out once in two or three days; and partly in the sack, which is now and then gently struck upon, both for shaking down the foot, and for clearing the interstices between the threads, so as to procure a sufficient draught of air through it. Considerable quantities of this foot are prepared also in some parts of England, particularly at the turpentine houses, from the dregs and refuse parts of the resinous matters which are there manufactured.

The foot arising in common chimneys from the more oily or resinous woods, as the fir and pine, is observed to contain more dissoluble matter than that from other woods: and this dissoluble matter appears, in the former, to be more of an oily or resinous nature than in the latter, spirit of wine extracting it most plentifully from the one, and water from the other. The oiliness and solubility of the foot seeming therefore to depend on those of the subject it is made from, it has been thought that lamp-black must possess these qualities in a greater degree than any kind of common foot. Nevertheless, on examining several

parcels of lamp-black, procured from different shops, I could not find that it gave any tincture at all, either to spirit or to water.

Suspecting some mistake or sophistication, or that the lamp-black had been burnt or charred, as it sometimes is to fit it for some particular uses, I prepared myself some foot from linseed oil, by hanging a large copper pan over the flame of a lamp, to receive its smoke. In this method the more curious artists prepare lamp-black for the nicer purposes, and from this collection of it from the flame of a lamp, the pigment probably received its name. The foot so prepared gave no tincture either to water or to spirit, any more than the common lamp-black of the shops. I tried different kinds of oily and resinous bodies, with the same event: even the foot obtained from fish oil, and tallow, did not appear to differ from those of the vegetable oils and resins. They were all of a finer colour than the lamp-black commonly sold.

Some foot was collected in like manner from fir and other woods, by burning small pieces of them slowly under a copper pan. All the foots were of a deeper black colour than those obtained from the same kinds of wood in a common chimney, and very little if at all inferior to those of the oils: they gave only a just discernible tincture to water and spirit, while the foots of the chimney imparted a strong deep one to both. The foot of mineral bitumens, in this close way of burning, appears to be of the same qualities with those of woods, oils, and resins: in some parts of Germany, as I am informed by a worthy foreign correspondent, great quantities of good lamp-black are prepared from a sort of pitcoal.

It appears therefore that the differences of foots do not depend altogether on the qualities of the subjects, but in great measure on the manner in which the subject is  
burnt,



burnt, or the foot caught. The soots produced in common chimneys, from different kinds of wood, resinous and not resinous, dry and green, do not differ near so much from one another, as those which are produced from one kind of wood, in a common chimney and in the more confined way of burning above-mentioned.

### III. *Black metallic calces.*

THE mineral *cobalt*, roasted till its arsenical parts are dissipated, becomes black; and being then melted with inflammable fluxes, yields a regulus, which likewise assumes a black colour by calcination. The same regulus is obtained from the artificial *saffire*, whose basis is the roasted cobalt, and which is employed for tinging glass blue; as also from the deep blue glass itself, called, when ground, by the painters *finalt*, and by the laundresses *powder-blue*. The cobalt, more valuable for these important products than for the property which occasions it to be here taken notice of, and which has hitherto been afforded chiefly by Saxony, has of late, by the encouragement of the Society for promoting arts, been discovered in our own country: in further searches for it, the property here mentioned may be of great assistance, those minerals, and those only, which calcine black, promising to be useful cobalts. Calces of iron, whether red, yellow, or of other colours, on being brought into fusion by the addition of vitreous bodies, give always a black colour to the glass if the quantity of iron is considerable. From copper also a black colour may be produced by fire, and applied to the staining and embellishing of certain stones, of which an account will be given hereafter towards the end of this history. I have not observed that any of the other metallic bodies are changed black in any circumstances by simple heat.

## S E C T. IV.

*Black produced by mixture.*I. *Black from Iron.*

**F**ROM infusions of certain vegetables, mixed with green vitriol, is produced a deep black liquor, of most extensive use for dyeing and staining black. To wool-len and silk it gives a permanent colour, although from linen, and other vegetable bodies, its blackness is discharged by washing.

The substances chiefly employed for producing this colour with vitriol, are the excrescences of the oak tree, called galls; of which there are two principal kinds, one said to be brought from the Levant, and the other from some of the southern parts of Europe, particularly Sicily and Romania. The former, called by authors Aleppo-galls, and in the shops of our dry-droppers blue galls, are generally of a bluish colour, or of a greyish or blackish verging to blueness, unequal and warty on the surface, hard to break, and of a close compact texture: the others, commonly called white galls, are of a pale brownish or whitish colour, smooth, round, easily broken, less compact, and of a much larger size. The two sorts differ in strength, but in other respects they appear to be of the same quality. The Aleppo or blue galls are the strongest: two parts of these are reckoned by the workmen to be equivalent to three of the white; and such comparisons, as I have made of the two, incline me to think, that the difference in their strength is rather greater than this proportion.

These excrescences appear to proceed from the juices of the oak tree issuing out through small wounds made by certain insects; which insects not being found in this climate, no galls are here produced; though other kinds of excrescences

excrefcences are frequent on our oaks, occafioned perhaps by infects of another kind. It is not, as might be thought, on any particular fpecies of the oak tree that galls are formed; for Mr. Ray fays, that in his travels abroad, he has feen them on the fame kind of oak with that which is common here.

All the parts of the oak tree feem to contain juices of nearly the fame general virtue with galls; for the leaves, the acorns, and more particularly the bark and wood, ftrike with vitriol a black or a deep colour approaching to blacknefs. There are many other vegetable fubftances which have a like effect in different degrees; as the leaves, fmall branches, and flowery clufters of the fumach tree, balauftine flowers, pomegranate peel, alder bark, bifort root, and thofe in general which are auftere, aftringent, or corrugating to the tafte; infomuch that turning a folution of vitriol black is looked upon as a fure teft of aftringency in vegetables. The power by which they produce this blacknefs, and their aftringency, or that by which they contract an animal fibre, and by which they contribute to the tanning of leather, feem to depend upon one and the fame principle, and to be proportional to one another. Of the other properties of this aftringent and colouring matter, little more is known, than that it is diffolved and extracted from the fubject both by water and fpirit of wine, and that it does not exhale in the evaporation of the liquors by heat.

Green vitriol commonly called copperas, the other ingredient in the black mixture, is a preparation of iron, made at Deptford, Blackwall, Newcastle, and fome other parts of England, by boiling old iron with an acid liquor which runs from certain pyritæ on being long expofed to the weather. By diffolving iron in the vitriolic acid, and  
crystallizing

crystallizing the solution, the same salt is obtained in a purer state.

When a decoction or infusion of the galls is dropt into a solution of the vitriol largely diluted with water, the first drops produce bluish or purplish red clouds, which soon mingling with the liquor tinge it uniformly of their own bluish or reddish colour. It seems to be on the quality of the water that this difference in the colour depends. With distilled water, or the common spring waters, the mixture is always blue. If we previously dissolve in the water the most minute quantity of any alkaline salt, too small to be discoverable by any of the common means by which waters are examined, or if the water is in the least degree putrid, the colour of the mixture proves purple or reddish. Rain water, caught as it falls from the clouds, in an open field, in clean glass vessels, gives a blue, but such as is collected from the tops of houses grows purple with the vitriol and galls; from whence it may be presumed, that this last has contracted a putrid tendency, or received an alkaline impregnation, though so slight as not to be sensible on other ways of trial.

Both the blue and the purple liquors, on adding more of the astringent infusion, deepen to a black, more or less intense according to the degree of dilution: if the mixture proves of a deep opaque blackness, it again becomes bluish or purplish when further diluted. If suffered to stand in this dilute state for two or three days, the colouring matter settles to the bottom in form of a fine black mud, which, by slightly shaking the vessel, is diffused again through the liquor, and tinges it of its former colour. When the mixture is of a full blackness, this separation does not happen, or in a far less degree; for though a part of the black matter precipitates in standing, yet so much remains dissolved, that the liquor continues black. This suspension  
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of the colouring substance in the black liquid may be attributed in part to the gummy matter of the astringent infusion increasing the consistence of the watery fluid, for the separation is retarded in the diluted mixture by a small addition of gum arabic; though another principle appears also to concur for part of the effect.

If the mixture, either in its black or diluted state, be poured into a filter, the liquor passes through coloured, only a part of the black matter remaining on the paper. The filtered liquor, to the eye perfectly homogeneous, on standing for some time becomes turbid and full of fine black flakes: being freed from these by a second filtration, it again contracts the same appearance, and this repeatedly, till all the colouring parts are separated, and the liquor has become colourless. It should seem therefore, that there happens a gradual and slow concretion of the black corpuscles, into particles large enough to subside by their own weight, or to be retained on a filter; and that this concretion is greatly influenced by dilution with water. Perhaps it is affected also by the action of the air; for having once set some of the diluted mixture to settle in a close stopp'd glass, the separation of the black matter was remarkably more slow than in the other experiments, in which the vessel was open.

The colouring matter, thus separated from the liquor, being drained on a filter and dried, appeared of a deep black, which did not seem to have suffered any change on lying exposed to the air for upwards of four months. Made red hot, it glowed and burnt, though without flaming, and became a rusty brown powder, which was readily attracted by a magnetic bar; though in its black state, the magnet had no action on it. The vitriolic acid, diluted with water and digested on the black powder, dissolved greatest part of it, leaving only a very little quantity

of whitish matter. Solution of pure fixt alkaline salt dissolved very little of it: the liquor received a reddish brown colour, and the powder became blackish brown. This residuum was attracted by the magnet after being made red hot, though not before: the alkaline tincture, passed through a filter, and mixed with solution of green vitriol, struck a deep brownish-black colour, nearly the same with that which results from mixing with the vitriolic solution an alkaline tincture of galls.

From these experiments it seems to follow, that the colouring matter in the black mixtures is iron, extricated from its acid solvent in a highly attenuated or divided state, and combined with a peculiar species of matter contained in astringent vegetables; which matter, after the watery fluid that the compound floats in has been separated, is in part extracted from the iron by alkaline liquors, and may thence be again transferred into fresh dissolved iron.

The blackness is generally attributed to the iron being barely revived from the vitriol in its metallic state; the black matter being supposed to be of the same nature with the impalpable black powder, into which fine iron filings are changed by lying for many months under water. But this black matter differs from that of our mixtures in two very material properties. It is attracted in its black state by the magnet; and when moistened and exposed to the air, it changes speedily into rust. The resistance of ours to the magnet and to the air proceeds doubtless from the combination of the other matter with the iron; and there appears some analogy, in regard to the manner of production, between this black substance and Prussian blue; one being a precipitation and coalition of dissolved iron with one species of matter, and the other with another: the principal difference is, that the substance combined with the iron in the Prussian blue defends the metal from the action  
of

of acids, which that in the black compound is unable to do.

I tried likewise solutions and different soluble preparations of iron, made with the nitrous, marine, and vegetable acids; as also an alkaline solution of it, obtained in Stahls method, by dropping into strong alkaline ley a solution of the metal made in the nitrous acid. All the preparations, in which the iron was dissolved by an acid, struck a black colour with astringents; but the alkaline solution gave only a reddish brown. In this respect also the tinging substance in our mixtures agrees with that of Prussian blue.

It has been affirmed, that solutions of iron in the nitrous and marine acids produce no blackness with astringents; and some trials, formerly made, led me into the same opinion. On re-examining this matter, the fallacy appeared to lie here; that those acids do not very readily satiate themselves with the iron, and that any considerable quantity of redundant acid in the solution prevents the blackness. The case is the same with the vitriolic acid also; and probably if we had not, in the vitriol itself, a saturated combination of this acid with iron, ready prepared for other uses, the vitriolic solutions would as often have been found to refuse striking a black colour, as the nitrous and marine.

After the blackness has been produced, the addition of any of these acids, and even of the vegetable in sufficient quantity, destroys it, by redissolving the ferruginous matter: hence the use of acids or acidulated liquors, for discharging stains made by the black mixtures, such as that of common ink. Alkalies also destroy the blackness, apparently on a different principle, by dissolving the astringent matter, and precipitating the iron nearly in the same ochery state, as they do from the simple acid solutions

of the metal. After the blackness has been discharged by an alkali, the addition of any acid, in such quantity as to satiate the alkali, restores it; and after its discharge by an acid, it is in like manner restored again by an alkali.

## II. *Black from silver.*

SOLUTION of silver in aquafortis, of itself colourless as water, dropt upon white bone or other like animal substances, produces at first no stain. In some time, sooner or later according as the subject is more or less exposed to the sun and air, the part moistened with the liquid becomes first of a reddish or purplish colour, which by degrees changes into a brown, and at length deepens to a black. Several kinds of stones and wood receive, from the same solution, purplish, reddish, bluish, brown, or black stains.

On what particular combination the colours here depend, has not as yet been explained, nor indeed, so far as I can find, examined. The following observations, which we owe to a paper of Mr. Schulze, in the first volume of the *acta naturæ curiosorum*, though they do not discover the cause of the effect, may contribute to its illustration.

White chalk, moistened with a solution of silver, and dried in the shade or by a fire, receives no colour: dried in the sun, or exposed to the sun after it has been otherwise dried, it becomes on the surface of a purplish black. When the earth is thoroughly moistened with the solution, if so much water be added, as will reduce it into a thin paste, the matter in this state also becomes coloured in the sun, though in the shade it acquires no tinge. The colour is produced only in those parts on which the sun shines: a thread applied on the outside of the glass, between it and the sun, occasions a corresponding uncoloured vein on the included matter; and hence distinct characters  
may



may be exhibited on the mass, by intercepting a part of the suns light by threads or cut paper.

I repeated these experiments, and observed that the colours produced were nearly the same with those which the solution of silver communicates to bone or ivory, except that they did not deepen to so true a black. The colour was entirely superficial; for when the matter, by now and then turning the glass in the sun, had been tinged all over to a reddish or brownish black, it appeared white again when shaken and mixed together. By continuing the exposure for many weeks, and frequently shaking the mixture that fresh surfaces of it might be successively acted upon by the sun, it became at length coloured, though weakly, throughout. The suns rays in december produced the same change as in june, and, so far as can be recollected, as speedily. The light of candles, and a gentle warmth from common fire, did not seem to affect the colour. In a considerable heat, greater than that of the sun in summer, the matter became brown, but without acquiring the black colour which the sun communicates.

I tried also several other earthy bodies, and found that those which dissolve in acids, the ashes of vegetables and of bones and horns, suffered the same changes as chalk and the other mineral calcareous earths. But powdered flint, however moistened and drenched with the solution, received no colour in half a years exposure to the sun. White clay, plaster-of-paris, and powdered talk remained also uncoloured; and even chalk itself previously fatiated with the vitriolic acid, so as not to be acted upon by the acid in which the silver was dissolved, suffered no change.

It should seem from these experiments, that in order to the production of a black stain from solution of silver, it is necessary that the subject moistened with it be not only exposed to the solar light, but that it contain some matter  
which

which the nitrous acid may dissolve preferably to the silver which it already holds dissolved. This is plainly the case in bones, horns, hair, marble, and several other bodies which are stained by the silver solution; though there are also some stones which are stained by it, as agate, in which a substance soluble by the acid has not yet discovered itself.

It may be observed, that the production of a dark colour from the action of the sun is not peculiar to solution of silver, or to a combination of this solution with soluble earths. When bismuth is dissolved in the nitrous acid, and afterwards precipitated by dilution with water, the precipitated powder, exceedingly white, soon becomes dark coloured in the sun, so as to require great care, in drying and keeping it, to preserve the whiteness, for which that preparation is valued. Mercurius dulcis, a combination of quicksilver with the marine acid, suffers a like change. The effect, however, is less considerable here than in the silver liquor; for though both preparations become dark, I have not observed blackness produced in either.

### III. *Black from Lead and Sulphur.*

LEAD, a metal which of itself makes a blackish mark on paper, yields colours more approaching to blackness in some of its dissolutions and combinations with other bodies. Solutions of lead made in acids, dropt upon paper or other white subjects, communicate no stain; but on being exposed to sulphureous vapours, or washed over with alkaline solutions of sulphur, the parts moistened with the solution of lead become immediately yellow, and soon after of a deep brown or black, according as the liquors were more or less saturated with the matters dissolved in them.

The production of this colour has not been applied to any important use, being regarded chiefly as a matter of curiosity,

curiosity, as affording the foundation of one of the writings called invisible or sympathetic. For this purpose, vinegar is strongly impregnated with lead, by boiling with litharge, cerusse, or other calces of the metal; or what amounts to the same thing, the common preparation called sugar of lead is dissolved in water: solutions of lead in aqua fortis answer the same end, except that, when written with, they are apt to corrode the paper. The sulphureous liquor is commonly prepared by boiling some orpiment, which is a natural mixture of sulphur and arsenic, in water with quicklime, till the water is strongly impregnated with the orpiment: in the room of this preparation may be used a saturated solution of common brimstone, made by boiling the brimstone either with quicklime, or in strong alkaline ley. Characters written with the lead solution, which when gently dried in the air are not to be distinguished from the rest of the paper, become of a legible deep colour, on passing over them a pencil dipped in the sulphureous solution. Those who amuse themselves with this experiment, have black characters in the neighbourhood of the invisible ones; which black ones are drawn with burnt cork, or other charcoal blacks, mixed only with water: by the wet pencil, these are washed off, at the same time that the others are made to appear.

If any acid be added to the sulphureous solution, a very offensive smell arises; and a solution of sulphur made in strong volatile spirits, prepared with quicklime, exhales a like smell. This penetrating diffusive vapour, particularly that of the last of these preparations, gives colour to the invisible writing with the lead solution at a considerable distance: though the writing be placed in the middle of a quire of paper, or of a pretty thick book, the vapour will soon reach it, and stain it brown or black. The colour

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is discharged by acids, and restored again by the sulphureous vapour or solution.

Calces of lead, melted with sulphur, form a black or blackish mass, which proves an useful matter for taking casts from medals, being considerably more tough than sulphur alone. For this purpose, equal parts of minium and flowers of sulphur are put in an iron ladle over the fire, till they soften into the consistence of pap, and are then kindled with a piece of lighted paper, and stirred for some time: the vessel being afterwards covered close and continued on the fire, the mixture becomes fluid in a few minutes, and is then poured upon the medal previously oiled and wiped pretty clean. This process, communicated to me by a friend, I have often tried with satisfaction. The casts are very neat; the colour, sometimes a pretty deep black, and sometimes a black grey, according to different circumstances in the fusion; they are very durable, and when soiled may be washed clean again with spirit of wine.

There are other metals also which produce a black colour with sulphureous bodies. When a solution of silver in aquafortis is added to a solution of sulphur made in alkaline ley, the silver and sulphur unite and precipitate together in the form of a black powder. Quicksilver and sulphur, by being barely rubbed together in a mortar, become black, and hence this mixture, commonly made for medicinal uses, is called the mineral ethiops. But as these kinds of compositions afford nothing of importance for the art of colouring black, it would be needless in this place to consider them more particularly.

#### IV. *Black from the combination of other colours.*

IN the three foregoing articles we have seen blackness generated from the action of certain bodies on one another,

other, and, in the preceding section, from alterations produced in the bodies themselves or their component parts. There is another general principle, on which some of the most common colours are obtained, the combination of two or more differently coloured bodies together, whence results a new colour compounded of those of the ingredients: thus green is formed from a mixture of blue and yellow, and purple from blue and red. These compound colours are found to succeed, by grinding together coloured earthy powders, by uniting coloured flames or the sun's beams which have passed coloured through glasses, by mixing dyed wool, threads, &c. where there can be no suspicion of any intrinsic change made in the subjects, or of any action of the ingredients on one another.

Mr. le Blon, in his harmony of colours, forms black on the same foundation, by mixing together the three colours called primitive, blue, red, and yellow; and Mr. Castel, in his *optique des couleurs*, published in 1740, says that this compound black has an advantage, in painting, above the simple ones, of answering better for the darkening of other colours. Thus if blue, by the addition of black, is to be darkened into a blue-black, the simple blacks, according to him, if used in sufficient quantity to produce the requisite deepness, conceal the blue, while the compound blacks leave it distinguishable.

Le Blon does not mention the proportions of the three primitive colours necessary for producing black. Castel directs fifteen parts of blue, five of red, and three of yellow; but takes notice, that these proportions are rather speculatively than practically just, and that the eye only can be the true judge; our colours being all very imperfect, and our pigments or other bodies, of one denomination of colour, being very unequal in its degree or intensity. He observes that the colours should each be the

deepest and darkest in its kind ; and that, instead of taking one pigment for each colour, it is better to take as many as can be got ; for the greater contrast there is of heterogeneous and discordant drugs, the more true and beautiful, he says, will the black be, and the more capable of uniting with all other colours, without suppressing them, and even without making them tawney.

The trials I have made of mixing different blue, red, and yellow powders, have not succeeded so far as to afford a perfect black ; but I have often obtained from them very dark colours, such as may be called brown-blacks and grey-blacks, such as we commonly see in the dark parts of paintings, and such as the charcoal and foot blacks appear when diluted a little. The ingredients being each of a dark deep colour is a very necessary condition ; for bright blues, bright reds, and bright yellows, mixed in such proportions that neither colour prevailed, produced only a grey. In effect, all compositions of this kind, physically considered, can be no other than greys, or of some of the intermediate tints between whiteness and blackness ; and these greys will be so much the lighter or darker, as the component colours of themselves are bright or dark. Some further experiments of producing a black by composition, for the purposes of dying and staining, will be mentioned in the sequel of this essay.

## S E C T. V.

*Black paints, varnishes, &c.*

### I. *Black paint with oil.*

**B**LACK oil paint is prepared, by grinding, with a proper quantity of oil, the charcoal or foot blacks, or the natural black earths, or pitcoal, till they are united into a smooth, uniform, thick compound, which is occasionally

sionally diluted with more oil, to a due consistence for being worked freely with the brush or pencil.

The finest black colour is made with ivory-black, ground, before the addition of the oil, into an impalpable powder. The material most commonly made use of is lamp-black, whose colour is for most purposes of sufficient deepness and beauty. The unctuousness of lamp-black gives it an advantage above the other pigments, of mixing more easily and perfectly with the oil; but from the same quality it receives a disadvantage, of being too slow in drying for the dispatch requisite in business. Some deprive it of this imperfection by burning it, that is, by heating it red hot in a close vessel; but being by this means reduced to the state of coal, it is deprived also of its easy miscibility with oil. It may, however, be made to dry as speedily as other oil paints generally do, by a due preparation of the oil; as particularly by setting it on fire and boiling it, in the manner hereafter described, in the tenth article of this section, for making printers ink.

The oil, for all paints, requires some preparation, to promote its own drying; and the method here recommended appears for this purpose both the most expeditious and the most effectual: The dark colour, which it commonly acquires in the process, and which renders it unfit for the brighter coloured paints, is of no inconvenience to it for blacks. The oil is made considerably thick by the boiling, and being in this state well mixed with the black matter, the mixture is diluted for use with unboiled oil, to which it communicates a sufficient degree of the drying quality desired.

## II. *Black paint with water.*

AN opaque deep black for water colours is made, by grinding ivory-black with gum water; or with the liquid

which settles from whites of eggs, after they have been beaten up and suffered to stand a little. Some use gum water and the white of eggs together; and report, that a small addition of the latter makes the mixture flow more freely from the pencil, and improves its glossiness.

It may be observed, that though ivory-black makes the deepest colour, in water as well as in oil painting, yet it is not always, on this account, to be preferred, in either kind, to the other black pigments. A deep jet black colour is seldom wanted in painting; and in the lighter shades, whether obtained by diluting the black with white bodies, or by applying it thin on a white ground, the particular beauty of ivory-black is in great measure lost: the same intentions may be answered by pigments of less price and more easily procurable.

A valuable black for water colours is brought from China and the East-Indies, sometimes in large rolls, more commonly in small quadrangular cakes, generally marked with Chinese characters. By dipping the end of one of the cakes in a little water, and rubbing it about on the bottom or sides of the vessel, a part of its substance is taken up by the water, which may thus be readily tinged to any shade of black or grey, from such as will just colour paper, to a full black. The composition of this Indian ink has not hitherto, so far as I can learn, been revealed; and I therefore made some experiments with a view to discover it.

Though the Indian ink is readily diffused through water, it is not truly dissolved: when the liquid is suffered to stand for some time, the black matter settles to the bottom in a muddy form, leaving the water on the top colourless; in the same manner as the common black pigments settle from diluted gum water. The ink, kept moist, in warm weather, becomes in a few days putrid,  
like



like the fluid or soft parts of animals; as does likewise the clear water, after the black matter has settled and been separated from it. The Indian ink appears therefore to contain an animal substance soluble in water; and to consist of a black powder mixed with some animal glue. For the greater certainty in regard to this conglutinating ingredient, I boiled one of the China cakes in several fresh portions of water, that all its soluble parts might be extracted, and having filtered the liquors through paper, set them to evaporate in a stone basin: they smelt like glue, and left a very considerable quantity of a tenacious substance, which could not be perceived to differ in any respect from common glue.

Being thus convinced of the composition of the mass, I tried to imitate it, by mixing some of the lamp-black, which I had myself prepared from oil (see page 342) with as much melted glue as gave it sufficient tenacity for being formed into cakes. The cakes, when dry, answered fully as well as the genuine Indian ink, in regard both to the colour, and the freedom and smoothness of working. Ivory-black and other charcoal blacks, levigated to a great degree of fineness, which requires no small pains, had the same effect with the lamp-black; but in the state in which ivory-black is commonly sold, it proved much too gritty, and separated too hastily from the water.

### III. *Composition for marking sheep.*

GREAT quantities of wool are annually made unserviceable by the pitch and tar, with which sheep are marked, and which are commonly not laid on with a sparing hand, as they considerably increase the weight of the fleece at a trifling expence. With a view to prevent, as much as possible, this great waste of so useful a commodity, the society instituted in London for the encouragement

ment of arts, manufactures, and commerce, and who continue vigorously and judiciously to prosecute the important ends of their institution, offered a considerable premium for the discovery of any cheap composition, that might supply the place of those hurtful materials; whose colour should be strong and lasting, which should bear the weather a proper time, and not damage the wool. Several proposals for this purpose were laid before the society, but none of them have as yet been thought deserving of the premium. The enquiry having been warmly recommended to me by the late Dr. Hales, as an object of very great importance to the woollen manufactory, I went through a set of experiments with this view in the year 1759.

It was hoped, that the ill qualities of tar and pitch might be corrected, by mixing with them some soap or size, which should prevent their too great adhesiveness, and render them so far dissoluble in water, as to be dischargeable from the wool by the means commonly practised for cleansing it; or, in failure of tar and pitch, that some composition of resins, oils, or fats might be found, which should be rendered harmless to the wool by the same correctors, and which should serve as sufficient cements for certain coloured powders, among which black appeared to be the best, as being the strongest and most conspicuous colour. On these principles many trials were made, but with little success: for the unctuous and resinous materials, with the advantage which they received from the soap or size, of being easily washed out from the wool, received also the disadvantage of being too soon discharged by the weather.

It was next considered, that as wool has always a natural greasiness, which the workmen wash out with stale urine, soap, or ley, as described in the sequel of this history;

tory; the common animal fats might probably be discharged from it by the same means, so as not to stand in need of those ingredients, from which the foregoing compositions had contracted the imperfection of being too easily dischargeable. Accordingly I melted some tallow; and stirred into it so much charcoal in fine powder, as made it of a full black colour, and of a thick consistence. This mixture, easily procurable and at small expence, being applied warm with a marking iron on pieces of flannel, quickly fixed or hardened, bore moderate rubbing, resisted the sun and rain, and yet could be washed out freely with soap, or ley, or stale urine. All the good qualities, that can be desired in a composition for marking sheep, appeared therefore to be united in this simple preparation.

Though the mixture of tallow and charcoal powder was found sufficiently durable when applied as above upon pieces of flannel; it occurred, that it might nevertheless, by the repeated attritions to which it is exposed on the body of the animal, be in danger of being rubbed off too soon. If we could add to the composition a little pitch or tar, we should effectually secure against any inconvenience of this kind, and it was apprehended that these ingredients might here be added with safety; for being perfectly dissolved by the tallow, it might be presumed that they would wash out along with it from the wool. Thus we see stains of tar got out from clothes by means of oil, which dissolving the tar, the whole compound is then discharged by the same detergents that the oil itself would be. I therefore melted some tallow with an eighth, with a sixth, and with a fourth of its weight of tar, and having thickened the mixtures with charcoal powder, spread them while hot upon pieces of flannel. None of the compositions could be discharged by any rubbing or washing with water. By soap they were all washed out completely;

completely ; that which had the smallest proportion of tar, easily enough ; that which had the largest proportion, difficultly. If therefore it should be feared, that the tallow will fail in point of durability or adhesiveness, which, however, I do not apprehend that it will ; it is plain, that as much as can be desired of this quality may be communicated, without damaging the wool, by a proper addition of the substances commonly made use of. I do not conceive that the nature of the thing can admit of any greater perfection.

There is a material circumstance in this affair, which does not seem to have been sufficiently considered by those who proposed the enquiry. If we could discover, which some have fruitlessly endeavoured to do, a staining composition in the nature of a dye, possessing all the good qualities that have been mentioned ; it would scarcely be possible, as matters stand at present, to induce the farmers to make use of it. They require a substance that will add weight : and I apprehend it will be no small recommendation to the above composition, that in this respect, as in all others except its being innocent to the wool, it agrees as nearly as can be expected, with the materials to which they have been long familiarized.

#### IV. *Composition for preserving wood, &c.*

THE great adhesiveness, which renders tar unfit as a principal ingredient, and excellent as a secondary one, for the purposes of the foregoing article, adapts it to another use, on some occasions not a little important ; the preserving of some kinds of wood on the outsides of certain buildings, the covering of sheds, paling, &c. as also for coating common tiles, in imitation of the black glazed tiles, which are sold at a much higher price.

**Tar**

Tar and pitch of themselves are too soft for these intentions; even the pitch being liable to be melted off by the heat of the sun in summer, however firm in the cold of winter. Different powdery substances, as ashes, ochres and other mineral pigments, have been mixed with them, but without remedying the imperfection so effectually as could be wished. In the Swedish transactions for the years 1742 and 1740, two compositions are recommended, which are said to be firm, durable, and glossy.

One is prepared by melting the tar over a moderate fire, so as to make it fluid but not to boil, and stirring in as much coal dust as will render it thick: this mixture, the author says, is to be laid on with wooden trowels, in a hot day, as thick or as thin as shall be thought proper. The other is prepared by mixing the melted tar with a sufficient quantity of lamp-black: a little of this mixture is spread upon the upper side of each tile with a stiff, short-haired, painting brush: next day, when dry, the tiles are done over with tar alone, and two days after with tar again: this coating being well dried, which in summer, according to the author, is generally in eight or ten days, some powdered lead ore is strewed over it, and well rubbed in, first with a coarse and afterwards with a fine linen cloth; from this it receives a sparkling appearance.

I tried both these compositions, and found them of a good black colour: when the bodies coated with them are held before the fire till the surface begins to run, they become glossy. They are not however wholly exempt from the inconveniencies complained of in the others. For though the tar was made as thick, both with the coal dust and lamp-black, as was consistent with its being spread smooth even in a hot sun and while warm from the fire, it afterwards softened in the sun considerably:

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though the parts, which the sun did not immediately shine upon, proved sufficiently firm in the hottest weather.

By coal dust, in the first composition, is meant powdered charcoal. Suspecting however that pitcoal, in virtue of its bituminous nature, might unite more perfectly with the tar, and be in some measure dissolved by it, I made trial of this also, chusing the finest coloured pieces, of those kinds which melt in the fire, and grinding them into impalpable powder. The mixture of this powder with the melted tar, made of such consistence as to be freely spread while warm with a brush, seemed to soften less in the suns heat than either of the other two. The durability of these compositions I cannot yet determine: after having stood, without any apparent alteration, one summer and winter, they continue exposed to the weather, for discovering what effects longer time and vicissitudes of seasons may have upon them.

The mixture of tar and lamp-black is found the most effectual preservative for the masts and yards of ships. Such parts of the mast, as the sliding up and down of the sails requires to be only greased, and those which are covered with turpentine or resin mixed with tallow or oil, generally contract large rents, while the parts coated with tar and lamp-black remain perfectly sound. I have been favoured by a gentleman on board of a vessel in the East-Indies, with an account of a violent thunder storm, by which the mainmast was greatly damaged, and whose effects on the different parts of the mast were pretty remarkable. All the parts which were greased, or covered with turpentine, were burst in pieces: those above, between, and below the greased parts, as also the yard arms, the round top or scaffolding, &c. coated with tar and lamp-black, remained all unhurt.

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In this place it may be proper to observe, that the coating or painting of wood does not in all cases contribute to its preservation: unless the wood be very thoroughly dry, especially those kinds of wood whose juices are not oily or resinous, the painting, by confining the watery sap, hastens the corruption. Several presses for a paper manufacture having been made of heart of oak seemingly very dry, some of them, which with injudicious care had been well painted over, rotted and perished in a few years, while the unpainted ones continued for many years perfectly found.

V. *Compositions for blacking leather.*

IN the tanning of leather, it is so much impregnated with the astringent parts of oak bark, or with that matter which strikes a black colour with green vitriol, that rubbing it over three or four times with a solution of the vitriol, or with a solution of iron made in vegetable acids, is sufficient for staining it black. Of this we may be convinced, by dropping a little of the solution on the unblackened side of common shoe leather. This operation is performed by the currier, who, after the colouring, gives a gloss to the leather with a solution of gum-arabic and lize made in vinegar. Where the previous astringent impregnation is insufficient to give a due colour, and for those sorts of leather which have not been tanned, some galls or other astringents are added to the solution of iron; and in many cases, particularly for the finer sorts of leather, and for renewing the blackness, ivory or lamp-black are used. A mixture of either of these with linseed oil makes the common oil blacking. For a shining blacking, small beer or water are taken instead of oil, in the quantity of about a pint to an ounce of the ivory-black, with the addition of half an ounce of brown sugar

and as much gum-arabic. The white of an egg, substituted to the gum, makes the black more shining, but is supposed to hurt the leather and make it apt to crack. It is obvious, that all these kinds of compositions admit of many variations: it is sufficient here to have given a general idea of them.

#### VI. *Spirit varnish.*

BLACK varnish, for jpanning on wood or leather, is prepared by mixing lamp-black or ivory-black with a proper quantity of a strong solution of gum lac in spirit of wine, such as that described in the preceding part of this work, page 224. The lamp-black is commonly preferred to the ivory-black, on account of its uniting better with the fluid, and working smoother. The thicker part of the varnish, which settles at the bottom, is used with the lamp-black for the first coatings, and the mixture applied at different times, in a hot room, one layer after another is dry, till a full body of colour is obtained: after which, the piece is washed over in the same manner, several times, with the finer part of the varnish, just tinged with the black, so as to make a coating of sufficient thickness to bear polishing with tripoli.

#### VII. *Amber varnishes for papier maché, &c.*

PAPIER maché is made of cuttings of white or brown paper, boiled in water, and beaten in a mortar, till they are reduced into a kind of paste, and then boiled with solution of gum-arabic or of size, to give tenacity to the paste, which is afterwards formed into different toys, &c. by pressing it into oiled moulds. When dry, it is done over with a mixture of size and lamp-black, and afterwards varnished. The black varnish for these toys (of which the first account I have seen is in a pamphlet on drawing,



drawing, &c. printed for Mr. Peele in 1732, and said to be taken chiefly from manuscripts left by Mr. Boyle) is prepared as follows.

Some colophony, or turpentine boiled down till it becomes black and friable, is melted in a glazed earthen vessel, and thrice as much amber in fine powder sprinkled in by degrees, with the addition of a little spirit or oil of turpentine now and then: when the amber is melted, sprinkle in the same quantity of sarcocolla, continuing to stir them, and to add more spirit of turpentine, till the whole becomes fluid: then strain out the clear through a coarse hair bag, pressing it gently between hot boards. This varnish, mixed with ivory-black in fine powder, is applied, in a hot room, on the dried paper paste; which is then set in a gently heated oven, next day in a hotter oven, and the third day in a very hot one, and let stand each time till the oven is grown cold. The paste thus varnished is hard, durable, glossy, and bears liquors hot or cold.

A more simple amber varnish, of great use for many purposes, and said to be the basis of the fine varnishes which we see on coaches, &c. is prepared, by gently melting the amber in a crucible till it becomes black, then reducing it into a powder, which looks brown, and boiling the powder in linseed oil, or in a mixture of linseed oil and oil of turpentine. Drying oil is commonly made choice of by the workmen; but it seems more eligible here to take the oil unprepared, that the boiling, requisite for giving it the drying quality, may be employed at the same time in making it act upon the amber.

By the previous melting of the amber, its nature is changed, and part of its oily and saline matter expelled, as happens in the common distillation of it. When the distillation is not far protracted, the caput mortuum, or  
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shining black mass which remains in the retort, answers as well as the amber melted on purpose. Hence some of our chemists, instead of urging the distillation to the utmost, by which the amber would be reduced to a mere coal, find it more advantageous to discontinue the process when the thinner oil and greater part of the salt have arisen, that the remaining mass may be in great measure soluble in oils, so as to supply the common demand of the varnish makers.

It has generally been thought, that amber will not at all dissolve in oils, till it has thus suffered a degree of decomposition by fire. Hoffmann relates an experiment, in his *observationes physico-chemicæ*, which discovers the solubility of this concrete in its natural state. Powdered amber, with twice its quantity of oil olive, was put in a wide-mouthed glass; and a digester, or strong copper vessel, being filled about one-third with water, the glass was placed in it, the cover of the digester screwed down tight, and a moderate fire continued an hour or more: when cold, the amber was found dissolved into a gelatinous transparent mass.

In Dr. Stockars very curious *specimen inaugurale de succino*, printed at Leyden, in 1760, there are sundry more important experiments on this subject, made by himself, conjointly with my worthy correspondent Mr. Ziegler of Winterthur. They found that by continuing a simmering heat twelve hours, and confining the vapour as much as stone-ware vessels would bear without bursting (the danger of which was avoided by making a small notch in the cork stoppers) powdered amber dissolved perfectly in expressed oils, in turpentine, and in balsam of copaiba: a strong copper vessel, with a cover screwed on it, seems most eligible, and for the greater security, a valve may be made in the cover, kept down by a spring that shall give way before

before the confined vapour is of sufficient force to be in any danger of bursting the vessel. Though such a heat as converts part of the oil into strong elastic vapours, and the forcible compressure of the vapour, are expedient for hastening the dissolution, they do not appear to be essentially necessary; for by digestion for a week in close stopt glass vessels, in which the compressure could not be very great, solutions equally perfect were obtained.

The solution in rape-seed oil, and in oil of almonds, was of a fine yellowish colour; in linseed-oil, gold coloured; in oil of poppy-seeds, yellowish red; in oil olive, of a beautiful red; in oil of nuts, deeper coloured; and in oil of bays, of a purple red. It is observable that this last oil, which of itself, in the greatest common heat of the atmosphere, proves of a thick butyraceous consistence, continued fluid when the amber was dissolved in it. The solutions made with turpentine, and with balsam of copaiba, were of a deep red colour, and on cooling hardened into a brittle mass of the same colour. All the solutions mingled perfectly with spirit of turpentine. Those made with the oils of linseed, bays, poppy-seeds, and nuts, and with balsam of copaiba and turpentine, being diluted with four times their quantity of spirit of turpentine, formed hard, tenacious, glossy varnishes, which dried sufficiently quick, and appeared greatly preferable to those made in the common manner from melted amber.

#### VIII. *Varnish for metals.*

IRON snuff-boxes, mourning buckles, &c. are coloured black, by making them considerably hot, and applying on them in this state a thick mixture of lamp-black, with a certain varnish called gold-size. There is a gold-size, formerly mentioned, for gilding, or fixing gold-leaf on wood, &c. The size here meant is a composition of a  
different

different kind, consisting of drying oil, turpentine, and the pigment called Naples yellow; which last ingredient is used for giving a high gold colour to the mixture, to fit it for some of the other purposes for which it is employed. In the present intention, the yellow might doubtless be omitted, and the varnish formed at once by mixing lamp-black with a proper quantity of turpentine and drying oil.

#### IX. *Sealing-wax.*

BLACK sealing wax is composed of gum lac, melted with one half or one third of its weight of ivory-black in fine powder. The inferior sort of lac, called shell-lac, answers as well for this use as the finest. It is customary to mix with it, for the ordinary kinds of sealing wax, a considerable proportion, as two thirds its weight, of the cheaper resinous bodies, particularly Venice turpentine, by which the beauty of the mass is here less injured than in the red wax, and of which a small addition is in all cases expedient, to prevent the compound from being too brittle. The ingredients being melted and well stirred together over a moderate fire, the mixture is poured out upon an oiled stone or iron plate, and rolled, while soft, into sticks, which afterwards receive their glossiness by being heated till the surface begins to shine.

The black figures on the dial-plates of clocks and watches, which look like black enamel, are formed of the finer kind of black sealing wax, which is melted into cavities made in the plate, and afterwards polished. Black enamel or stones are some times imitated in the same manner in other works.

#### X. *Printing*

X. *Printing ink.*

PRINTING ink differs from the common oil paint, described at the beginning of this section, only in the preparation of the oil, which must here have its consistence and tenacity greatly increased, and its greasiness diminished, by means of fire. The same way of preparation, either not carried to so great a length, or with a subsequent addition of fresh oil to dilute the mixture, affords, as already observed, one of the best drying oils for the black paint.

The oils of linseed and nuts are made choice of for this use: the nut oil is supposed to be the best, and is accordingly preferred for the black ink, though the darker colour which it acquires from the fire makes it less fit for the red. It is said that the other expressed oils cannot be sufficiently freed from their unctuous quality; whence the ink made with them dries exceeding slowly, is apt to come off and smear the paper in the beating and pressing which it undergoes in the book-binders hands, or sinks into the substance of the paper, beyond the mark of the type, and stains it yellow.

Ten or twelve gallons of the oil are set over the fire, in an iron pot, capable of holding at least half as much more; for the oil swells up greatly, and its boiling over into the fire would be very dangerous. When it boils, it is kept stirring with an iron ladle; and if it does not itself take flame, it is kindled with a piece of lighted paper or burning wood; for simple boiling, without the actual accension of the oil, does not communicate a sufficient degree of the drying quality required: it seems to be in the more inflammable parts, which are soonest consumed by the burning, that the injurious fatness or greasiness consists. The oil is suffered to burn for half an

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hour or more, and the flame being then extinguished by covering the vessel close, the boiling is afterwards continued, with a gentle heat, till the oil appears of a proper consistence: in which state it is called varnish. It is necessary to have two kinds of this varnish, a more and less boiled, or a thicker and a thinner, which are occasionally mixed together as different purposes may require: that which is of a just consistence in warm weather proves too thick in cold; and that which answers well for large characters, proves in the same season rather too thin for small ones.

The thickest varnish is of such consistence when cold, that it draws into threads between the fingers nearly like weak glue: this is the mark by which the workmen judge of the due boiling, a little of it being from time to time taken out for this trial, and cooled by dropping it on a tile or other cold body. It is very viscous and tenacious, like the soft resinous juices or thick turpentine. It is not at all dissolved, any more than the oil at first, by water or spirit of wine, but mingles readily enough with fresh oil, and unites with mucilages into a mass which dissolves in water into a milky liquor: by boiling with strong alkaline ley it forms a soapy compound; whence the types, after an impression, are cleaned from the ink, by washing, and rubbing them with a brush, in hot ley. The oil emits, during the whole time of the boiling, very offensive penetrating fumes: when grown cold, it has an acrid disagreeable taste, but little ill smell. The oil is said to lose, in being boiled into thick varnish, from a tenth to an eighth part of its weight, which proportions agree sufficiently with my trials: common linseed oil, boiled down to a consistence which appeared somewhat too thick, lost about one sixth: being further boiled, till it became quite firm when cold, the loss was near one half. Different

rent oils, and perhaps the same oil in different states, differ in this respect: fish oil, boiled to thickness, lost much more than that of linseed, the thick matter amounting only to about one fourth of the original weight of the oil.

The workmen are accustomed to add, in the preparation of ten or twelve gallons of oil, as soon as the burning is over, a pound or two of dry crusts of bread, and a dozen or two of onions, by which they suppose the greasiness to be more effectually destroyed. It may however be questioned, whether additions of this kind are of much use; for I have prepared the varnish, seemingly of a very good quality, by fire alone.

There is another sort of additions whose effect is more apparent. To give a greater body to the varnish, and increase its drying quality, a proportion of turpentine is thought necessary; and with some artists, litharge has in this intention been a secret. It is observed, in the French *encyclopedie*, by Mr. le Breton, the printer of that work, that when very old oil is used, neither turpentine nor litharge are needful; but that, when the oil is new, some turpentine must necessarily be employed, for without it, the smearing of the paper, by the spreading or coming off of the ink, cannot be avoided; that it is much more eligible to use old oil than to have recourse to this correction of the new, both turpentine and litharge, particularly the last, making the mixture adhere so firmly to the types, that it is scarce to be got entirely off by the ley, whence the eye of the letter is soon clogged up.

When turpentine is used, it is first boiled by itself, untill, on dipping in a piece of paper, it is found to crumble and part from the paper when cold: the oil being then taken from the fire, the turpentine, while still fluid, is poured into it, after which the boiling is repeated, and continued till they are sufficiently incorporated.

It is here somewhat more difficult to hit the due point of boiling, than when the oil is prepared without addition; the mixture being more apt to grow too thick from continuing the heat too long, and full of little hard grains from not continuing it sufficiently; which grains are probably undissolved particles of the turpentine. The use of boiling the turpentine first by itself is to dissipate its moisture or essential oil: by the boiling it becomes a resinous matter, nearly the same with common resin, which possibly would answer the same end.

For making the varnish into ink, lamp-black is the common material; of which, according to Mr. le Breton, two ounces and a half are sufficient for sixteen ounces of the varnish. They are ground together on a stone with a muller, in the same manner as oil paints.

The paper, for printing, is moistened with water; by which it is made more yielding and pliable, so as not only to be less apt to be torn by the types in the press, but likewise to be more closely and evenly applied to them, and consequently to take a neater and more perfect impression. The due moisture of the paper, and the care and attention of the pressmen in well working the ink on the types with the balls, are very material points; without which, how excellent soever the ink is, the impression will not be beautiful.

The adhesion of printers ink to wetted paper seems to shew that it is not truly of an oily nature. All expressed oils contain probably a gummy or mucilaginous matter; and perhaps the tenacity, consistence, drying quality, and the property of adhering to bodies moistened with water, which the oil acquires in the process above described, may be all owing to some of the purer part of the oil being destroyed, so as to leave the remainder more gummy. When the oil dries, it proves a tough flexible substance,



stance, which has little disposition to unite with fresh oil any more than with water, as if the gummy and oily matter were in such proportions, that one defends the other from the menstruum that would otherwise dissolve it: essential oils on the contrary, being free from gum, harden into a merely resinous mass, brittle like other resins, and which dissolves, like the oil at first, in fresh oil or in spirit of wine. The differences observed in different expressed oils, in regard to the drying quality, may depend on the different quantities of gummy matter; and the difference of old oil from new, on the gum being in the latter more intimately combined, so as not to separate in the burning and boiling. When these oils are first pressed out from the subjects, they abound with mucilage, great part of which is only superficially mixed, so as to give a turbidness and opacity to the fluid: in keeping, a part of this loose mucilage is thrown off, and the remainder may be presumed to become at the same time more intimately incorporated with the oil. The repugnance which we observe between oil and gum does not in the least invalidate these conjectures, any more than the repugnance between oil and water can be an argument against the existence of water in oils: indeed we have plain proofs of the coalition of oil with gum, in the analysis of the purest gums, gum arabic, fenica, tragacanth, from which an actual oil is obtained by distillation. The distillation of expressed oils themselves seems to favour the opinion here proposed: from all of them there remains in the distilling vessel a large quantity, though from some more than from others, of a gross coaly matter; and there arises a fluid oil, which does not dry or grow thick in the air as the oils did at first; and which is therefore found to answer for certain purposes, as in the lapidaries business,

business, for which the thickening of the oils in their natural state renders them unfit.

### XI. *Rolling-press Ink.*

BETWEEN the rolling-press printing, and that of the printers press strictly so called, there is this essential difference; that in the former the impression is received from figures hollowed in a copper plate, but in the latter from prominent types. The damping of the paper is equally necessary for the rolling-press as for the other, in order to soften it, so that the parts, corresponding to the cavities in the plates, may be forced into them. But the ink is of a somewhat different quality. For while the printers types require a glutinous or sticky mixture, which shall adhere upon the prominences of the type, without running into the hollows; the ink for copper-plates must run into and fill the hollows, especially when the plate is warmed, and be so little glutinous, as to be easily wiped off clean from the smooth parts of the plate, or those which are to leave the paper white.

The oil, for this ink, must be boiled, and set on fire, in the same manner as for the other, to take off its greasiness and promote its drying: the boiling is continued more or less, according to the different consistences which different kinds of plates may require, but never so far as to communicate to the oil the adhesive gluey quality of the printers varnish. The black matter must be of the charcoal kind: the lamp-black gives always a degree of toughness, but the charcoal blacks, as they do not unite intimately with the oil, divide its texture, and render it less gluey. The coal commonly employed for this use is brought in powder from Germany, and called German or Frankfort black: this is softer, and more free from grittiness,

ness, than the ivory or other charcoal blacks as usually prepared among us.

The Frankfort black is supposed by some to be the coal of vine-twigs ; by others, that of the kernels of fruits and wine lees burnt together. The coal of vine-twigs, as we have already seen, does not appear to differ, in any great degree, from that of the small branches of other kinds of trees ; but the kernels of fruits yield a coal considerably more soft and mellow, easily crumbling between the fingers into a fine meal. That the Frankfort black is no other than a vegetable coal, appeared from its burning on a red hot iron, like charcoal powder, into white ashes ; and from the ashes, like common vegetable ashes, being plentifully dissoluble by the vitriolic acid into a bitterish liquor, while the ashes of animal substances are very sparingly affected by that acid, and form with it a compound of a different kind of taste.

## S E C T. VI.

### *Of the preparation of common writing ink.*

**C**OMMON writing ink is prepared from galls, or other astringent vegetables, and green vitriol, steeped or boiled in water or other liquors. The ingredients, in different receipts, are set down in very different proportions : in some, six parts of galls are directed to one of vitriol ; and in others, three or four parts of vitriol to one of galls : some order the weight of the liquor to be equal to that of the vitriol and galls together, others fifteen or sixteen times as much.

Most of the common inks have a capital imperfection, that though at first of a pretty good colour, yet in length of time they decay, some sooner and others later, the writing becoming scarcely legible, or even entirely disappearing ;

pearing; of which too many instances are known to those, who have examined records and other writings of any considerable age. The preparation and improvement of this useful fluid, on whose duration so much depends, becomes therefore a very important object.

The ingredients being known, it was hoped, that by a proper set of experiments, the best ink they are capable of affording, in regard both to the durability and beauty of the colour, could not escape discovery. Though length of time be the proper test of the absolute duration of inks, it was presumed that a few years would be sufficient for judging of their comparative durability; and that in this comparison, some assistance might be obtained from exposing the writings for some months to the sun and weather, by which the influence of time on colours is hastened in a remarkable degree: dyed clothes exposed for a month or two to the sun in summer, lose more of their colour, than they do in an age when kept close from the air. With these views, about fifteen years ago, I engaged in a set of experiments, of which the general results are as follow.

*I. Experiments for determining the best preparation of ink with vitriol and astringents.*

WHEN common ink, or a black infusion of galls and vitriol, is diluted largely with water, and suffered to settle, the black matter, as already observed, falls to the bottom, and the liquor becomes colourless. If such a mixture contained more vitriol than the galls could saturate and decompose, it was judged that the redundant vitriol would remain dissolved in the liquor, and strike a black colour with fresh galls; and that on the contrary, if the quantity of galls employed at first was more than sufficient for the decomposition of the vitriol, the liquor would in like  
manner

manner retain the redundant impregnation of the galls, and strike a blackness with fresh vitriol; so that by trying, till such proportions of the two should be found, as that the liquor, after the precipitation, should produce no blackness with a fresh addition of either ingredient, the proportions requisite for the exact saturation might be discovered.

Many trials were accordingly made on this principle. When the quantity of galls was several times greater than that of the vitriol, an addition of more vitriol to the liquor after settling produced a fresh blackness; and when the vitriol greatly prevailed, an addition of galls had the like effect. But there were several intermediate mixtures, with proportions considerably different from one another, in which no blackness could be perceived to arise from the addition of one or the other ingredient. By taking a medium between the quantities, in those trials where one or the other did produce a sensible colour, it was reckoned that about equal parts of the two were the mean proportions, which could receive no additional blackness from a further increase of either. In these and all the other experiments made with galls, the Aleppo or blue galls were the sort employed; and care was taken, by boiling or long infusion, to get out as much of their virtue as can be expected to be done in practice.

Different infusions of the galls and vitriol, in a more and less dilute state, were tried next on paper. Here it was found, that the proportions, which gave the greatest blackness, were not those, whose colours were the most durable, though in both respects there were considerable latitudes. Equal parts of the two, the quantities which the foregoing way of trial seemed to point out for the best, gave an ink of good blackness at first; but on keeping for a few weeks, and in a few days when exposed to

the sun and open air, the writing changed to a yellowish brown. The mixtures, in which the vitriol exceeded the galls, underwent greater and speedier changes; more and more so, according as the excess of the vitriol was the greater. Those in which the galls exceeded the vitriol were more durable: an infusion of two parts of galls and one of vitriol did not fade so much in two months exposure, as an infusion of equal parts of the two did in one month; and three parts of galls to one of the vitriol made an ink which held its colour still better. When the galls were increased to five or six times the weight of the vitriol, the colour did not prove black enough, though it seemed to be rather of more durability than the others.

The writings which had changed to a brown or yellow, I washed over with an infusion of galls. Where the ink had been well loaded with the ingredients, the characters became of a pretty good black; and those, which had been written with more dilute inks, became, though not black, yet sensibly more coloured than before, inso-much that many, which had grown almost indistinguishable, were now sufficiently legible. How far this infusion would serve for the recovery of decayed writings of great age, I have not had an opportunity of trying; but thus-much is clear, that a distilled water of galls, recommended for this purpose in Caneparius's collection *de atramentis*, cannot answer; the astringency, or the power of giving blackness to iron, residing in such parts of the galls as do not rise in distillation.

It seems to follow from the above experiments, that the decay of inks is owing chiefly to a deficiency of galls; that the galls are the most perishable ingredient, the quantity, which gives the greatest blackness at first, being insufficient to maintain the colour; that for a durable  
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ink, the quantity of galls cannot be much less than three times that of the vitriol; and that it cannot be much greater without somewhat injuring the ink in point of blackness.

The proportion of liquid admits of much greater latitude, than that of the vitriol and galls to one another. One ounce of vitriol, three ounces of galls, and a hundred and fifty ounces of water, made an ink, legible indeed, though greatly too pale. With a hundred ounces of water to the same quantity of galls and vitriol, the colour was still too pale. With forty and fifty ounces of water, the ink was of sufficient blackness for common uses: but the fullest and blackest colour of all was produced when the quantity of liquor was little more than enough to cover the powders, as six, eight, or ten ounces. It was expected that these small quantities of water, dissolving all the vitriol, without being able to fully extract the virtue of the galls, and thus occasioning a deficiency in the quantity of astringent matter, would have yielded a perishable ink. Nevertheless, characters written with these mixtures have preserved their colour for fifteen years, continuing still sensibly blacker than where the menstruum was in larger quantity. It appears therefore, that though a large portion of fluid may be tinged by the vitriol and galls of a blackness sufficient for many purposes, the using a little quantity is of advantage both to the deepness and durability of the colour; perhaps only from the liquor being in this case more loaded with the colouring matter of the ingredients, so that a greater body of colour is accumulated upon the stroke.

I next tried what alteration would result from the using of different waters or other liquors for the menstruum. Distilled water, rain water, and hard spring water, employed in the same proportions, had, so far as could be

judged, the same effects. White wine produced an ink of a deeper black colour than the waters; and with vinegar, the colour was rather still deeper. Proof spirit extracted only a reddish brown tinge, and rectified spirit a paler brown, the vitriol not being dissoluble in these liquors. Both the spirituous tinctures sunk and spread upon the paper, that in rectified spirit more than the other: hence the addition of spirit to common ink, directed by some for preserving it from mouldiness, or from freezing in winter, occasions generally a precipitation of part of the colour, and makes the ink sink, more or less according to the quantity of the spirit. The coloured juices of fruits, as of privet-berries, mulberries, black-cherries, used as menstruums for the galls and vitriol, made the colour rather fuller on first writing than water did, but it was less black, and soon grew dull or rusty in keeping. A decoction of logwood, used instead of water, sensibly improved both the beauty and the deepness of the black, without at all disposing it to fade.

Instead of the galls, I tried other strong astringents, as oak bark, alder bark, sloe bark, sumach, tormentil root, bistort root, balauftine flowers, pomegranate peel, &c. but could not find one of equal efficacy with galls. Nor did any but the oak bark seem to give the same species of blackness that galls did, most of the others having more or less of a greenish hue: the oak bark itself however, though it came nearest to the galls, made a very bad ink, and though used in eight or ten times their quantity, was far from being equal to them in effect. The saw-dust of oak wood, which has lately been found to answer for tanning leather, as well as the bark or rather better, and consequently to have no inconsiderable impregnation of true astringent matter, produced with vitriol a tincture somewhat different from all the other astringents I have tried:



tried: the colour at first was an opake deep blue: after the liquor had stood for some days on a fresh quantity of the wood, it approached more to blackness; but still retained a very considerable blue tinge. Galls themselves give indeed a bluish colour when the liquor is diluted so as to be transparent; but in an opake state, so far as I have observed, they exhibit no blueness.

I made trial also of the juice of floses, which to the taste is pretty strongly astringent, and which, as we have formerly seen, page 332, gives of itself, to linen, a stain of remarkable durability. By mixing the juice, whether of raw or of baked floses, with different proportions of solution of vitriol, I could not produce the least tendency to blackness, the vitriol seeming to make little alteration in the colour. Some of the mixtures, however, having been written with on paper, the characters, after standing for several days exposed to the air, changed by degrees to a full black, which appeared to be more durable than that of any of the inks made with galls; their colour having stood well in the open air from the beginning of november last, till the papers were destroyed by the weather in the end of february. Writings with good common ink, exposed along with them as a standard, had faded much.

As all the astringent vegetables communicate of themselves some colour to water, galls a brownish, bistort root a dark brown, logwood a purplish, tormentil root a reddish, pomegranate peel a greenish yellow, &c. I endeavoured to prepare a compound black from the astringents alone, on the principles mentioned at the end of the fourth section, page 355; hoping that this additional black in the liquor might coincide with, and heighten, that which the vitriol would produce with the direct astringent matter. Accordingly, taking a decoction of galls  
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and logwood for the basis, I infused successively in this liquor several different astringents, till at last its colour approached pretty near to blackness. By dissolving in the dark blackish liquor a due quantity of vitriol, I obtained a good ink indeed, but not at all better, so far as could be judged, than if the decoction of galls and logwood only had been used. Perhaps the vitriol, uniting with the properly astringent parts, and thus suppressing some of the component colours of the black infusion, destroyed at once all the blackness which resulted from the combination of the colours.

Instead of the vitriol, or vitriolic solution of iron, I tried saturated solutions of the metal in other acids. With the nitrous and marine acids, the ink was too corrosive, though made as dilute as it could bear to be consistently with a due colour; nor was the colour so true a black as that of the vitriolic ink, the marine acid inclining it to blue, and the nitrous to brownish green. Though the using of vinegar, for dissolving the vitriol, was of advantage to the colour; yet a solution of iron, made in vinegar only, gave a very bad ink. A solution of iron, made by boiling iron filings in water with tartar, and separating the unsaturated tartar by crystallization, &c. produced with galls only a rusty brownish colour. A solution of iron in lemon juice answered better than those in vinegar or tartar, but did not seem to come up to the vitriolic solution.

As the iron of the vitriol, and the astringent matter of the galls, unite together into a new compound, which is the tinging matter of the ink; it may be presumed that the acid, which held the iron dissolved, is extricated, at least in part, and remains loose in the liquor. Suspecting this disengaged acid to be a principal cause of the change of the inks to a rusty colour, I endeavoured to separate it,  
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by adding to a black infusion of vitriol and galls a little quicklime; this earth having the property of imbibing the vitriolic acid, and forming with it a selenitic compound, which will not remain dissolved in the liquor. The ink was far from being anywise improved by this addition. A very small quantity of the lime made no sensible change in the colour of the liquor; but a larger quantity turned it reddish brown, the lime seeming to have nearly the same effect as alkaline salts have. After the writings with these mixtures had been exposed to the sun and weather about two months, those with the larger proportions of lime could not be read; and those with the smallest quantities had faded more than the ink by itself.

I then endeavoured to separate the acid in another manner. Some good ink was diluted with water, that the colouring matter might settle; and the black sediment was washed repeatedly with fresh portions of water, that whatever saline matter it contained might be extracted. The black matter thus prepared was mixed with water in which some gum arabic had been dissolved. Writings with this mixture were of great durability: after hanging about four months against a south wall, they had contracted no rusty hue, though they were grown much paler than at first, and rather grey than black: perhaps even this change proceeded in part from some of the colouring matter being washed off by rain. It is the capital imperfection of mixtures of this kind, that after the colouring matter has been separated from the liquor, it cannot be again incorporated with watery fluids near so perfectly as it was before in the ink: it can only be diffused through the water in a powdery form, as the charcoal powders are, and settles from the liquor, and may be washed off from paper, almost as easily.

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The most effectual way of preventing any ill effects from this redundant acid seems to be by an addition of iron itself; part of which, in proportion as the iron of the vitriol is extricated, will be dissolved in its place, and thus continue both to satiate the acid, and supply one of the essential ingredients of the ink. It should seem that in this method, a much less proportion of acid, that is, a less quantity of vitriol, would suffice, than is otherwise necessary; the same acid serving to combine with the galls fresh quantities of the iron: and in such case, keeping for a length of time, as a year or more, would improve the ink. Of this I have not yet had full experience; but a friend informs me, that he has seen writings of more than eighty years standing, which continued of a full black colour, without any tendency to yellow or brown; that the ink was made in the common manner with vitriol and galls, and long kept with pieces of iron in the vessel. Possibly boiling for a little time might answer the same purpose as long keeping; for boiling remarkably promotes the separation of iron from vitriol, and consequently the action of the acid on fresh iron.

Gum arabic is added to inks, to give a greater consistence to the fluid, and enable it better to keep the colouring matter suspended: it contributes, perhaps, to prevent the black matter from concreting into particles large enough to settle by their weight, as well as to prevent or retard their settling after they have so concentered; for we have seen in a foregoing part of this essay, that the coalition into sensible particles is successive, and that before it happens, the black matter is in so subtile a state, that it may be considered as being in actual dissolution.

The gum appears also to be of another advantage, preventing the ink from spreading upon the paper, so that a greater quantity of the fluid, and consequently a greater  
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body of colour, is collected on each stroke. An infusion of vitriol and galls was mixed with different proportions of common water, and with the same proportions of a solution of gum arabic in water : all the mixtures with gum water, written with on paper, were at first, and still continue, very manifestly deeper coloured than those which had been equally diluted with plain water. In an ink which had an over proportion of vitriol, and which, when written with, soon lost its blackness and turned to a yellowish brown, I dissolved as much gum as it would bear without becoming too thick to run freely from the pen : the colour was not only deepened, but made greatly more durable; partly perhaps, from the greater quantity of colour in the strokes, and partly from its being in good measure defended by the gum from the action of the air.

Gum arabic, gum fenica, and the plum and cherry tree gums dissolve in the ink almost as easily as in pure water. But isinglass, a glue prepared from a kind of fish, would not at all mingle with it : when the isinglass was previously dissolved by itself in water, and the solution poured into an infusion of the galls only, the fish-glue, immediately on mixture, begun to curdle and separate. Solutions of common glue or size seemed however to mingle uniformly enough with the ink, no sensible coagulation or separation ensuing.

Sugar, sometimes added to inks, is much less effectual than gum, either as a coat for defending the colouring matter on the paper, or for preventing its precipitation from the liquor. It even hastens the precipitation of some part of the colour, and is accompanied with another inconvenience, that of making the ink exceeding slow of drying. The shining hue, which the sugar communicates, is by no means sufficient to counterbalance its disad-

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vantages; and besides, where this quality is desired, an almost equal glossiness may be obtained by means of gum.

I tried likewise to prepare an ink, in which the colouring parts should be secured by a resinous varnish. Here no water could be used, the dissolution of the resin requiring strong spirit of wine; and as this spirit does not dissolve the vitriol of iron, another preparation of the metal became necessary. Iron filings were digested in spirit of salt, with a moderate heat, till the acid would dissolve no more; and the solution being set to evaporate till it became thick, it was in this state diluted with rectified spirit of wine: this preparation is the *tinctura martis in spiritu salis* of the apothecaries. I made a strong tincture of galls in spirit of wine, and dissolved in it as much mastich as it would take up: with this solution poured off clear, I mixed different proportions of the tincture of iron, and obtained bluish-black liquors, of a pretty good blackness when written with, and sufficiently durable, but unfit for the common purposes of ink, on account of their spreading and sinking in the paper, and growing clotty in the pen. Part of the mastich seemed to be precipitated on mixture with the tincture of iron, as resinous bodies generally are with acids; whereas gums dissolve in acids without precipitation.

Instead of the preparation of iron, called green vitriol, some have recommended the blue vitriol of copper, and others the white vitriol of zinc. The white vitriol, though its principal metallic matter be zinc, generally contains also no inconsiderable quantity of iron, and in virtue of this iron it strikes a black with galls. Many blue vitriols also have a mixture of iron with the copper, and in this case they may in like manner strike a black with astringents. To common green vitriol I added different proportions of the pure vitriols both of zinc and copper:

copper: the inks prepared from these mixtures were not equal to those made with the green vitriol only. I tried also another preparation of copper, verdegriſ: a ſmall addition of this made the colour of the ink remarkably deeper on firſt writing, but this additional blackneſs did not ſtand, and the colour turned ruſty much ſooner than when no verdegriſ was uſed. The effect of this ingredient will be further conſidered in the next ſection.

In ſome receipts for ink, the galls are directed not to be powdered, but only bruifed, or broken into three or four pieces. To ſee if this precaution could be of any advantage, I cut ſome galls into four pieces each, and ſome into bits like large pins heads: another parcel was reduced into pretty fine powder. Equal weights of the three were digeſted for a fortnight, with vitriol and water in equal proportions: the ink from the large pieces was conſiderably paler than the other two, and that from the powdered galls was the deepeſt coloured.

A ſmall wooden caſk, or a ſtone bottle, is commonly choſen for making ink in, and the veſſel is generally kept ſtopt. As air appears to contribute to the deepening of the colour of ink upon paper, the characters not acquiring their full blackneſs till a day or two after writing, it ſeemed probable, that a free admiffion of air might have a like effect upon the ink in its fluid ſtate, and conſequently that a broad ſhallow open veſſel, and frequent ſtirring, ſo as to expoſe freſh ſurfaces to the air, would contribute to improve the colour, and make the ink flow black from the pen. Accordingly mixtures of galls and vitriol with different proportions of water, were expoſed to the air in flat ſtone-ware diſhes, and ſtirred nine or ten times a day for a month. The liquors wrote blacker than thoſe made from the ſame quantities of the ingredients in cloſe veſſels; but whether the difference

proceeded only from part of the water having evaporated, so that the quantity of liquid was made less, or from the instrumental efficacy of the air deepening the colour as it does that of ink written with on paper, was not fully apparent from the experiments: probably it depended on both causes conjointly.

For obtaining an ink that should write black at once, on many occasions a very desirable point, I tried another method, similar to that by which the dyer produces expeditiously a deep black on cloth. The dyer first boils the astringent materials in water for a considerable time, and then adds the vitriol and slackens the heat, so that the liquor may never fully boil after the vitriol is put in. By this way of management, the ink was made to write of a pretty deep colour, much more so than those prepared by long continued cold maceration.

It may here be proper to give a caution against the use of copper vessels for ink. Mr. Marggraf relates, that when solution of pure vitriol of iron is boiled with copper, part of the iron is precipitated in an ochery form, and the liquor becomes strongly impregnated with the copper, which in this dissolved state, as we have already seen, debases the colour of ink. I have found that copper is dissolved also by mixtures of vitriol with astringents; for having used a copper pan in experiments of dying black, related in the following section, the liquor, immediately after the addition of the vitriol to the astringent decoction, shewed plain marks of its having taken up a portion of copper, by giving a coppery stain to an iron knife with which it was stirred. Mr. Marherr, in an ingenious inaugural dissertation on the chemical affinities of bodies, printed at Vienna in 1762, gives an observation more decisive of the effects of copper vessels: when the best inks were kept in a copper ink-stand, so  
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much of the copper was dissolved, that the writings became in a short time as ill-coloured, as if the ink had been of the worst kind. It is pretty singular that the vitriolic acid, in its separation from the iron, should dissolve a body, on which otherwise, in so dilute a state, it does not seem to have any action. Leaden vessels are also observed to be corroded by ink, and debase its colour; and probably, except the materials of which ink itself is composed, all the other bodies, that the vitriolic acid is capable of dissolving, will be found injurious to ink.

II. *Composition of ink, deduced from the experiments.*

THE foregoing experiments point out, for the best proportions of the ingredients, one part of green vitriol, one of powdered logwood, and three of powdered galls. The best menstruum appears to be vinegar or white wine, though for common use water will suffice. The quantity of menstruum admits of great latitude: to make an ink of a full body of colour, it should not exceed a quart, or at most three pints, to three ounces of the galls, and one ounce of each of the other two ingredients. The proportion of gum may be varied at discretion, according as the ink is wanted to be more or less glossy or shining, or as the nature of the paper may require the fluid to be well gummed to prevent its sinking: half an ounce to a pint is in most cases sufficient; though the more gum we can employ, consistently with due freedom of writing, it is probable that the ink will be the more durable.

The ingredients may be all put together at once, in any convenient vessel, and well shaken four or five times a day. In ten or twelve days, and sooner if set in a warm place, the ink will be fit for use; though both its colour and durability will be improved by standing longer on  
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the undissolved ingredients. The ink thus prepared, though it flows pale from the pen, turns to a good black in a day or two after writing.

Or the logwood and galls may be first boiled in the liquor for half an hour or more, with the addition of a little more liquor to make up for that which evaporates in the boiling. Strain the decoction while hot, and having put it into the vessel which the ink is to be kept in, add to it the vitriol and the gum: as soon as these are dissolved, the ink may be used. By this way of managing the process, we obtain all the advantage of boiling, and the separation of the gross feculence, without daubing any other vessels or utensils than the ink-vessel itself: the ink is expeditiously made, and writes of a pretty full colour.

Common pale ink, prepared by cold maceration, may be improved, so as to write black at once, by evaporation. It may be set in such a heat as will make it visibly steam, not greater; and the heat continued until, on trying the liquor now and then, it is found to be of sufficient blackness. On the same principle, when ink is kept in an open ink-stand, till it begins to grow somewhat thick from the exhalation of part of the watery fluid, it writes as black as can be wished; and when grown too thick to be conveniently written with, it gives blackness to a certain quantity of fresh ink. Hence, when we have pale ink to be thus improved, it will be sufficient, in many cases, to evaporate to blackness only a part of it, and to dilute this occasionally, as it thickens in the ink-stand, with some of the rest, stirring them well together after each addition, as the thickened and dilute inks do not very readily unite; if the evaporation was suffered to continue till the black matter remained dry, it would scarce dissolve at all in common ink or in water.

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There is another method of giving blackneis to inks, by the addition of some of the black pigments formerly mentioned; but the use of these pigments for writing will make the subject of another article at the end of this section.

As the galls and logwood ought to be in pretty fine powder, that their virtue may be more readily and effectually extracted, it is expedient to have the ink separated from them, as in the second of the above processes; because otherwise the ink will often be loaded with the finer parts of the powder in substance, which being mixed up by shaking the vessel, remain long suspended in the liquor. It is proper, however, in order to secure against any danger of a deficiency in the astringent materials, to add to the ink separated from its feculence, some galls in coarse powder freed from the fine dust by a sieve. On the same principle, an oaken cask is one of the best vessels for keeping ink in, this wood having a manifest astringency, and answering nearly the same end with the additional galls. Besides the galls, some pieces of iron may be put into the vessel, as mentioned in page 386.

### III. *Of the preparation of the paper for durable writing.*

THE dyers, as we shall see hereafter, prepare their cloth for receiving a permanent black colour, by boiling it with galls, that it may be thoroughly penetrated by the astringent parts of the galls before the vitriol is introduced; so that wherever the vitriol can reach, it meets with astringent matter, to unite and produce a black with.

It is observable, that writings first begin to fade or change their colour on the back of the paper, where the larger strokes have sunk in or are visible through it; as if part of the iron matter of the vitriol was in a more subtile or dissolved state than the rest, and sunk further  
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into the paper, on account of its not being fully disengaged from the acid, or sufficiently combined with the astringent matter of the galls.

Hence it should seem probable, that if the paper was impregnated with astringent matter, the colour of the ink would be more durable; and that therefore a practice similar to that of the dyer, would be a valuable addition to the business of the paper-maker.

To see how far this notion was well founded, I dipped some paper in an infusion of galls, and when dry, repeated the dipping a second and a third time. On the paper thus prepared, and on some of the same paper unprepared, I wrote with different inks; several of which, that the effect might be more sensible, had an over proportion of vitriol. The writings being exposed to the weather, till the best of the inks on the unprepared paper had faded and changed their colour, those on the prepared paper were all found to retain their blackness.

It is therefore recommended to the consideration of the paper-makers, whether a particular kind of paper might not be prepared for those uses where the long duration of the writing is of principal importance, by impregnating it with galls, or other astringents, in some of the operations which it passes through before it receives the glazing; as for instance, by using an astringent infusion, instead of common water, in the last operation, when the matter is reduced into a pulp for being formed into sheets. The brownish hue, which the paper receives from the galling, would not perhaps be any great obstacle to its use; and if the proposal should be thought worthy of being carried into execution, further enquiries may possibly discover means of obviating the imperfection, and communicating astringency without colour.

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An astringent matter might be introduced also into parchment and vellum. The common tanned skins, as already observed, and not only those of the softer kind but the firm soles of shoes, have the very impregnation, which we here propose to communicate to the finer skins used for writing. I steeped a thick piece of parchment in water, along with some oak bark, for three or four days, and having then pressed it smooth and dried it, I found it as effectually penetrated with the matter which makes ink durable, as the paper in the experiment before mentioned. Even when the surface of the parchment was pared off, and the internal part written upon, the characters continued of a good black, while those made with the same ink, on unprepared parchment, were changed to a yellowish brown.

It may here be observed, that an impregnation of paper with one or both of the ingredients of ink, has been sometimes already practised, in a more imperfect manner, and with a view rather to amusement, than to the answering of any useful purpose. Galls in fine powder being well rubbed into the paper with a hares foot, a solution of vitriol, made so dilute as to have little or no colour, writes black upon the paper so prepared, forming with the galls, in all the parts it touches, an extemporaneous ink upon the surface of the paper. If powdered vitriol be first rubbed in, the same blackness is produced by infusion of galls; and if powdered galls and powdered vitriol be mixed and applied together, both in a very dry state that they may not act upon one another, plain water makes a black writing.

But though practices of this kind should in some cases be convenient; as for making occasional minutes, in want of ink, with common watery fluids; or for the purpose mentioned by Boyle, the keeping of the fingers from being

blackened, by using colourless fluids for writing with; it is plain, that the inks thus produced must be in greater danger of fading than those made in the common manner, as the proportions of the ingredients, which form the ink, cannot be ascertained, and will be different on different parts of the paper. The preparation before recommended depends on a different principle, in regard both to the intention and the means: for here the preparation is only superficial, while there it is diffused through the substance of the paper: the intention here is only the producing of a black colour on the surface, by applying a fluid which has no blackness, while there the paper is impregnated with the material which is most perishable in ink, in order to continue the blackness beyond the period in which that of the ink itself would decay.

#### IV. *Attempts to prepare an ink from more durable materials.*

To introduce into writing the ink whose permanence we see daily in printed books, appeared so desirable an object, that though there were small hopes of attaining it, its importance seemed to deserve some trials.

Printers ink, as we have seen in the foregoing section, is a thick mixture of lamp black and oil; and such a mixture, though diluted with more oil, is evidently unfit for writing. Instead of oil, I mixed both lamp black and ivory black with solution of gum arabic, made of such consistence as just to flow sufficiently from the pen. The liquors wrote of a fine black colour, but when dry, part of the colour could be rubbed off, especially in moist weather, and a pencil dipped in water washed it away entirely.

I tried solutions of the animal glues, with the same event. Isinglass or fish-glue being the most difficultly dissoluble of these kinds of bodies, I made a decoction of it  
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in water, of such strength, that the liquor concreted into a gelly before it was quite cold: with this gelly, kept fluid by sufficient heat, I mixed some ivory black: characters drawn with this mixture on paper bore rubbing much better than the others, but were discharged without much difficulty by a wet pencil.

It was now suspected, that the colour could not be sufficiently fixed on paper without an oily cement. As oils themselves are made miscible with watery fluids by the intervention of gum, I mixed some of the softer printers varnish, already described, with about half its weight of a thick mucilage of gum arabic, working them well together in a mortar, till they united into a smooth uniform mass: this was beaten with lamp black, and some water added by little and little, the rubbing being continued, till the mixture was diluted to a due consistence for writing. It wrote freely, and of a full brownish-black colour: the characters could not be discharged by rubbing, but water washed them out, though not near so readily as any of the foregoing. Instead of the printers varnish or boiled oil, I mixed raw linseed oil in the same manner with mucilage and lamp black, and on diluting the mixture with water, obtained an ink not greatly different from the other.

Though these oily mixtures answered better than those with simple gums or glues, it was apprehended that their being dischargeable by water would render them unfit for the purposes intended. The only way of obviating this imperfection appeared to be, by using a paper, which should admit the black liquid to sink a little into its substance. Accordingly I took some of the more sinking kinds of paper, and common paper made damp as for printing; and had the satisfaction to find, that neither the oily nor the simple gummy mixtures spread upon them so

much as might have been expected, and that the characters were as fixed as could be desired, for they could not be washed out without rubbing off part of the substance of the paper itself.

All these inks must be now and then stirred or shaken during the time of use, to mix up the black powder, which settles by degrees to the bottom: those with oil must be well shaken also, though not used, once a day, or at least once in three or four days, to keep the oil united with the water and gum; for if once the oil separates, which it is apt to do by standing at rest for some days, it can no longer be mixed with the thin fluid by any agitation. But though this imperfect union of the ingredients renders these inks less fit for general use than those commonly employed, I apprehend there are many occasions, in which these kinds of inconveniences will not be thought to counterbalance the advantage of having writings, which we may be assured will be as lasting as the paper they are written upon. And indeed the inconvenience may be in great measure obviated by using cotton in the ink-stand, which, imbibing the fluid, prevents the separation of the black powder diffused through it.

It has often been remarked, that the inks used in former times were far more durable than those of later years; many modern records being more decayed than the manuscripts of much greater antiquity. Camillo Paderni, in his letters from Herculaneum published in the Philosophical Transactions for the years 1753 and 1754, speaking of the ancient Roman, and Greek volumes discovered there, written on the Egyptian papyrus, complains of the paper being so much decayed and rotten, that they have been able to unroll only a few pieces, but makes no complaint of the ink having anywhere faded, all the parts that have been unrolled seeming, from what  
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he says of them, to be legible enough: in one place he mentions expressly the characters being of a very black tincture, exceeding that of the coal to which some parts of the paper were reduced. This observation occurring to me on revising the foregoing experiments, I was induced to look into the Greek and Roman writers, who flourished before the destruction of that city, to see if any account could be found in them of the ink they made use of.

On this enquiry it plainly appeared, that the ancient inks, whose great duration we now admire, were no other than such as we have been proposing in the present article. Pliny and Vitruvius expressly mention the preparation of soot, or what we now call lamp black, and the composition of writing ink from lamp black and gum. Dioscorides is more particular, setting down the proportions of the two ingredients, to wit, three ounces of the soot to one ounce of gum. It seems the mixture was formed into cakes or rolls, which being dried in the sun, were occasionally tempered with water, as the cakes of Indian ink are among us for painting. It may be observed, that the Indian ink is still the writing as well as the painting ink of the Chinese. The Chinese writing indeed is performed in the same manner as painting, with a stiff hair pencil fixed in the end of a reed: but the Romans used a pen, and the inks of this kind are found to answer with a pen nearly as well as those now commonly used. It might be matter of curiosity at least, and perhaps of utility, for those who have proper opportunities, to enquire more particularly into the preparation of ink in different nations and different ages, and the legibility of the manuscripts of the respective periods.

I have already taken notice, that all the inks, made on the principle we are now speaking of, can be discharged by  
washing,

washing, unless the paper admits them to sink into its substance. The ancients were not insensible of this imperfection, and sometimes endeavoured to obviate it, according to Pliny, by using vinegar, instead of water, for tempering the mixture of lamp black and gum. I tried vinegar, and found it to be of some advantage, not as giving any improvement to the cement, but by promoting the sinking of the matter into the paper. As this washing out of the ink may be prevented, by using a kind of paper easy enough to be procured, it is scarcely to be considered as an imperfection; and indeed, on other kinds of paper, it is an imperfection only so far as it may give occasion to fraud, for none of these inks are in danger of being otherwise discharged than by design. The vitriolic inks themselves, and those of printed books and copper plates, are all dischargeable; nor can it be expected of the ink maker to render writings secure from frauds.

Our experiments and reflections on inks having thus led us back to the practice of the ancients, a further improvement occurred, that of uniting the ancient and modern inks together; or using the common vitriolic ink, instead of water, for tempering the ancient mixture of gum and lamp black. By this method it should seem that the writings would have all the durability of those of former times, with all the advantage that results from the vitriolic ink fixing itself in the paper. Even where the common vitriolic mixture is depended on for the ink, it may in many cases be improved by a small addition of the ancient composition, or of the common Indian ink which answers the same purpose: when the vitriolic ink is dilute, and flows so pale from the pen, that the fine strokes, on first writing, are scarcely visible, the addition of a little Indian ink is the readiest means of giving it the due blackness. By this admixture it may be presumed also that the vitriolic  
ink

ink will be made more durable, the Indian ink in some measure covering it, and defending it from the action of the air. In all cases, where Indian ink or other similar compositions are employed, cotton should be used in the ink-stand, as already mentioned, to prevent the settling of the black powder.

Though the foregoing enquiries have not attained to the perfection which might be desired, I flatter myself that they will not be found unimportant; that even the unsuccessful experiments, if they contribute nothing in a philosophic view, will at least have this use, that they will lessen the labour to others who may engage in the same pursuit; that a composition of ink has been given, of as black and durable a colour, as there are grounds to believe the materials to be capable of producing; that an improvement has been proposed in the manufacture of paper, by which the duration of inks will be greatly prolonged; and that means have been pointed out of obtaining, for purposes where such duration is required, writings as lasting as the paper itself, with fewer inconveniences, than those, which for all occasions of writing, men acquiesced in for ages without complaint.

## S E C T. VII.

### *Of the dying of woollen black.*

#### I. *General observations on the black dye.*

**T**HE ingredients from which common writing ink is prepared, green vitriol and astringent vegetables, make the basis of the black dye; the dying of cloth black being no other than the producing of an ink in its pores, or impregnating it with the colouring parts of ink already made. There are, however, some variations in the composition.

position of the dying ink if it may be so called; mixtures, which prove too perishable when applied superficially on paper, being of sufficient durability when introduced into wool or woollen cloth; and mixtures, which make a good black ink on paper, making only a brown in the dyers business.

2. Cloth is generally supposed to be weakened by the black dye, more than by any other; on account of the corrosive quality of the vitriol, which is increased by the heat made use for making it thoroughly penetrate the subject: though the vitriol of iron is much less corrosive than the solutions of the metal made in the nitrous and marine acids, it is reckoned much more so than the alum and tartar employed in most of the other dyes. The finer the black, the more it is thought to weaken the cloth; inso-much that some writers look upon the beauty of the colour, and its durability or innocence to the cloth, as being incompatible with one another, and hence think it advisable to abate a little in both points, and to be satisfied with a colour of moderate fineness that the cloth may be moderately lasting. A German writer on dying, distinguished by the approbation of the celebrated Stahl, places this affair in a somewhat different light. He observes that the vitriol proves corrosive only so far as it is not saturated with the galls, and that by using a proper quantity of galls, it will be mortified, so as to be incapable of doing any injury to the cloth: to determine the quantity sufficient for this complete saturation, he directs a decoction of the galls, and a solution of the vitriol, to be mixed together in different proportions, and dropt upon white paper, the liquors being made very dilute that their colours may be the better judged of: the proportions, which give the deepest black colour, are those which ought to be followed by the dyer, and by which, according to him, the vitriol is  
made

made harmless. The experiments in the foregoing section have shewn, that about equal parts of galls and vitriol produce the full blackness on paper; and our dyers, so far as I can find, have generally employed the galls in a proportion not less than this, or at least supplied their deficiency by a quantity of other astringents equivalent in virtue; from whence it should follow, that the common black dye cannot hurt the cloth. In this point I have not myself had any fair experience, but am assured by a skilful and judicious dyer, that black, properly dyed, has by no means the corrosive quality generally attributed to it; and that the rottenness or perishableness, often complained of in black cloths, &c. proceeds only from the cloth having been damaged before the dying, for black is the dye commonly had recourse to for damaged and unfaleable pieces, and such as have been spoilt in other dyes. Though vitriol, however mortified, be admitted to weaken the cloth, it is pretty clear that black is not the dye which weakens it most; for vitriol is used for some coffee colours, not indeed with quite so great a heat but in greater quantity than for the black dye itself; and the aquafortis employed in scarlets, oranges, and some other colours, is certainly more corrosive.

3. For dying black, especially on superfine cloths, it is customary to give a previous ground of some other deep colour; and blue is preferred for this ground, as being one of the most innocent dyes in regard to the cloth, and as being of all colours that which has the nearest affinity to black: common black ink, and the black liquor of the dyer, when diluted largely with spring water, appear blue, as if their blackness was no other than a concentrated blue. The use assigned for this blue ground by the writers on dying is, that the cloth, having already a considerable body of colour, may require less of the blackening

materials, and consequently be less weakened, than if it was dyed directly from white to black. But there is another more important use of it, the blue being essential to the production of the black dye; for without either a blue ground, or a blue superadded to the vitriol and galls, no other than brown dyes are obtained. There are means, (see hereafter N<sup>o</sup>. 7.) of introducing this necessary blueness along with the vitriol and astringents; but the colour proves more perishable than when dyed upon a blue ground of indigo or woad.

4. The dyers commonly leave some blue marks at the ends of the cloth, by fixing pieces of lead on them, by which they are secured from the action of the black liquor, to shew that the piece has been regularly dyed on a blue ground, and consequently that the colour may be expected to be durable. This may be discovered, with greater certainty, by steeping a small bit of the black cloth, for a day or two, in water acidulated with a little oil of vitriol; or more expeditiously, by boiling it about a quarter of an hour, in a solution of alum and tartar, made in the proportion of an ounce of each of the salts to a pint of water. Great part of the black matter being destroyed or dissolved by the saline liquors, the cloth will remain of a bluish black colour if it has had a previous blue ground; but if it has been dyed directly from white, it will now look of a muddy reddish brown. The solution of alum and tartar is the essay liquor for black cloths, directed in the new French regulations, which were drawn up from the experiments of Dufay, and published at the end of Hellots *Art de teindre*.

5. Stuffs, whose price will not admit of the blue dye, are said, by the French and German writers, to be grounded with a deep brown, by boiling them with walnut peels, or walnut-tree roots. This practice, as I am informed,

informed, is never followed by our dyers, who look upon brown as a colour opposite to black, and therefore very unfit to serve as a ground for it. Whether a brown ground is useful or otherwise I cannot take upon me absolutely to determine; but thus much I can affirm, that I have known brown stuffs dyed to a black, which was reckoned, by good judges, to look, and to hold its colour in wearing, remarkably well. It should seem that any deep colour, which does not hurt the cloth, would be preferable to white; and it may here be proper to observe, that all colours whatever receive a black dye, though black will not receive any other; whence black, as already mentioned, is the last resource for cloths that have been damaged or had their colour stained or impaired by different accidents.

6. The excellent regulations for the French dyers, drawn up and published by the order of Mr. Colbert, require the cloth, after it has been blued, to be maddered. In order to fix the colour of madder, the cloth must be first boiled with alum and tartar; and as these salts must necessarily contribute to augment the ill qualities that were supposed to result from the black dye itself, and which were endeavoured as much as possible to be avoided, it might be thought that the madder was accompanied with some considerable advantage, sufficient to counterbalance that inconvenience and the addition which it makes to the expence. It has not been found however, on fair trials, to contribute any thing either to the beauty or duration of the black. Mr. Hellot relates, that having dyed a piece of cloth of a deep blue, he maddered one of the halves, and then dyed both the maddered and unmaddered halves black in one copper: both turned out of a good black, but the unmaddered, he says, was plainly the best, the maddered piece having somewhat of a rusty

hue. The best way of comparison is, by placing samples of the dyed pieces flat, against a full light, that is, with their edges towards the light, and then going back a little, so as to look partly down upon them, and partly over the surface: this is the way in which the dyers judge of colours. On viewing in this manner several samples of blacks dyed on blue cloth maddered and unmaddered, I could not perceive that they differed greatly from one another, but was convinced, that if the maddered ones are not inferior to the others, they certainly have no advantage above them. In some of the old receipts, madder is directed as an ingredient in the black dye itself, along with the vitriol and galls; but here it is evidently superfluous, its colour not fixing itself in the cloth. Among the reasons alledged for the use of maddering the cloth, there is only one which appears to have any plausibility, viz. that it prevents the black cloth from staining the skin or linen; but all that the madder can do in this respect, as Mr. Hellot justly observes, is, to discharge the superfluous blue, and this not in virtue of the madder itself, but of the boiling with alum and tartar preparatory to the madder dye. The same advantage may be obtained by sufficiently scowering the cloth in the fulling mill after the dye. This is evident from the superfine cloths dyed by our dyers, among whom the injudicious and unfrugal practice of maddering, from such information as I have received, appears to be unknown. They have indeed a colour called madder black, dyed on baize, (a kind of coarse cloth stuff) for Portugal and Spain; but this depends on another principle, as will appear hereafter.

7. Logwood, which as we have seen in the foregoing section is a very useful ingredient in writing ink, is still more so in the black dye. Vitriol and galls, in whatever  
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proportions they are used, produce no other than browns of different shades : I have often been surpris'd, that with these capital materials of the black dye I never could obtain any true blackness in white cloth, and attributed the failure to some unheeded mismanagement in the process, till I found it to be a known fact among the dyers. Logwood is the material which adds blackness to the vitriol and gall brown ; and this black dye, though not of the most durable kind, is the most common. On blue cloth, a good black may be dyed by vitriol and galls alone ; but even here, an addition of logwood contributes not a little to improve the colour.

8. The addition of verdegris, which deepens the colour of the inky liquor, is found also to deepen the dye on cloth ; and this improved blackness, very perishable in the ink applied on paper, appears in cloth to be more durable, though not entirely so much as could be wish'd. The effect of the verdegris seems to proceed from its action on the logwood : for with galls, and with green vitriol, separately, it produced no tendency to blackness ; but with decoction of logwood it struck immediately a deep black, which when diluted appeared of a fine blue. This experiment reconciles two observations I have lately met with, one by Mr. Scheffer in the Swedish Transactions, the other by Mr. Hoffmann in a German treatise of œconomical chemistry, &c. the former of whom relates that logwood with verdegris gives a blue dye, and the latter that it gives a black. Blue is the proper colour of the mixture, and the black is a concentration of the blue. Part of the colouring matter of the mixture concretes very speedily into sensible particles, so as to look like a black powder diffus'd through the liquor : the liquor is found to pass blue through a filter, and the black matter, which remains on the filter, appears likewise

wife merely blue, when spread thin on paper, or diluted with white powders.

9. Instead of the verdegris, I tried a cheaper preparation of copper, blue vitriol. This had somewhat of a like effect, but in a less degree: the colour on mixture was less black, and the concretion of the colouring parts less remarkable: the black or bluish-black matter being separated by filtration, the liquor proved not at all blue, but purplish or reddish, much like a decoction of logwood by itself; it soon turned to a blue colour when dropt on paper and exposed to the air, but both the blue and the black were greatly more perishable than those produced by verdegris.

10. Some have preferred vitriols impregnated with a little copper, as that of Dantzick, to the more purely ferruginous English vitriol; not indeed suspecting that the copper would add anything to the colour, as in the foregoing experiments; but from an opinion of its rendering the vitriol more penetrating or corrosive, so as to enable the colouring matter to sink better into the subject. With regard to its adding colour, if the vitriol of copper was even as effectual in this intention as verdegris, which it is very far from being, yet the very small quantity, contained in the vitriols recommended, could be of no material advantage; and as to the penetration, I believe it will be admitted, that vitriol of iron without any copper is penetrating and corrosive rather more than enough. The Dantzick vitriol appears however to have one advantage, not depending on its coppery part, but on the manner of its preparation: greatest part of the English vitriol, by hasty crystallization, is run into large irregular masses, abounding with loose ochery matter and with watery moisture, if not with foreign substances of another kind; while the Dantzick, more slowly crystallized, is more  
pure,

pure, less watery and consequently stronger. The most perfect vitriol of iron is that which is in the most solid regular crystals, of the deepest green colour; not rusty or yellowish, from its containing an ochre unfatiated with acid; nor pale, from its being too watery, or holding aluminous or other foreign matter.

11. For producing a black dye on cloth, the cloth is first impregnated with the astringent matter, and afterwards passed through a solution of vitriol mixed also with astringents. If it was first charged with the vitriolic solution, the colour would not succeed so well, and the cloth would be more damaged: if the astringent and vitriolic liquors were mixed together at first in one copper, the operation would be prolonged, and several repeated dippings would be necessary for introducing into the subject a due body of colour. In the dying of great lengths of cloth, where sometimes there is an interval of a quarter of an hour between the passing of the two ends into the liquor, a little tartar is often added, which does not affect the colour itself, but is supposed to make the dye take more uniformly, and prevent the cloth from being what the workmen call bloted.

12. If after the cloth has acquired a full black colour, it be again and again passed through the dying liquor, its colour by no means receives any improvement, but is rather debased and inclined to brownish. An over-quantity of the ingredients, employed at first, has a like effect. The less quantity of the blackening materials we make use of on blue cloth, provided they are sufficient to give full blackness, the more durable will the colour be in wearing.

13. The proportions of the ingredients to one another, are regulated on quite other principles than in inks. Equal parts of vitriol and galls seem to be the best proportions.

portions. If the galls are much increased, which it is necessary they should be for ink, they make the dye incline to brown; but an increase of the vitriol, by which inks are made so perishable, does not appear at all to affect the dye: even the largest additions of vitriol, however they may weaken the cloth, do not seem to injure the colour.

14. In the dying of black, as of most other colours, there are considerable variations in the practices of different workmen, which it would be difficult and even useless to collect. I shall here describe two processes, which I have often tried in small, and which appeared to me to be the best.

## II. *Black with galls, logwood, and vitriol.*

A HUNDRED pounds of woollen cloth, dyed first to a deep blue, require, for the black dye, about five pounds of vitriol, five of galls, and thirty of logwood. These, as I am informed by an experienced artist, are the quantities generally allowed by our dyers.

The galls, beaten into moderately fine powder and tied up in a bag, are boiled for a little time in a copper of water sufficient for working the cloth in. The blued cloth, after being steeped in river water and drained, that it may be every where thoroughly moist, but not so as to drip, is in this state put into the boiling decoction of the galls, and kept turning therein for two hours or more, the bag of galls being now and then squeezed, that the virtue of this drug may be more effectually extracted and communicated to the cloth.

The logwood, rasped or shaved into small chips, or rather ground into powder, is boiled in another copper for several hours, this wood giving out its colour exceedingly difficultly. The logwood liquor is most commonly prepared

prepared a considerable time before it is used, its colour being found to improve in keeping.

The logwood decoction being made of a scalding heat, but not quite boiling, the vitriol is thrown into it, and as soon as this is dissolved, the galled cloth is put in. A boiling heat should never be used after the addition of the vitriol, not only as it would needlessly augment the corrosive power of the salt, but likewise as it would injure the beauty of the colour, by hastily extricating part of the ferruginous matter of the vitriol in an ochery form, before it can come sufficiently in contact with the astringent substance with which the cloth is impregnated. The cloth is incessantly turned in the liquor that it may receive the colour uniformly, and now and then taken out and aired for a moment, which contributes to secure the colour, and at the same time affords an opportunity of judging of its deepness.

After about two hours continuance in the dye, the cloth is found to have received a good black, and is then taken out, washed with cold water, and passed through the fulling mill. The superfine cloth is three times fullled, with warm solution of soap, which not only discharges the superfluous colour that would otherwise stain the skin or linen, but contributes also to soften the cloth itself by mortifying the acid.

### III. *Black dye with verdegris.*

FOR some of the superfine black cloths, a little verdegris is used by our dyers, and this addition appears among the French to be more frequent. Mr. Hellot, after trial of sundry processes, gives the following as being the best, or as that which produces the finest velvet black on cloth, and which accordingly is followed in the best dye-houses in France.

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For a hundred pounds of blue cloth; ten pounds of logwood chips, and the same quantity of Aleppo galls in powder, are tied up together in a bag, and boiled in a middling copper, with a suitable quantity of water, for twelve hours.

One third of this decoction is taken out into another copper, and two pounds of powdered verdegris added to it. In this mixture, kept gently boiling; or rather only scalding hot, the cloth is dipt, and turned without ceasing, for two hours; after which it is taken out and aired.

Another third of the decoction is laded out into the same copper, eight pounds of green vitriol added, and the fire slackened about half an hour. The vitriol being now all dissolved, the cloth is put in and worked for an hour, and then taken out and aired again.

The remaining third of the decoction in the first copper is then put to the other two in the second, the bag of galls and logwood being well pressed out. Fifteen or twenty pounds of sumach are now added; and as soon as the copper begins to boil, two pounds more of vitriol are thrown in, with some cold water to slacken the heat. The cloth is kept in for an hour, then taken out and aired, dipt a second time, and kept turning for an hour longer.

The cloth, now compleatly dyed, is washed in a river, and scowered in the fulling mill till the water comes from it colourless. It is then passed through a copper of weld or woold, prepared as for dying yellow, which is supposed to soften the cloth and confirm the colour.

This process affords a very fine black, but it is too expensive to be followed by our dyers, the fire, and manual labour of the black dye as here described amounting to more, as I am informed by a person conversant in this business, than the dyer is paid for the whole dye of the  
above

above quantity of superfine cloth, including the blue ground. The quantities of vitriol and galls may be diminished, and the time of boiling greatly shortened. The passing through weld liquor, after scowering with soap, is entirely unnecessary; though probably it may be of use where the scowering is not complied with; not however in virtue of the weld itself, but of the alkaline salt with which the decoction of it is generally prepared by the dyers, so that the weld liquor does no more than supply the place of soap.

Both in this and the foregoing process, the liquor remains black after the dying of the cloth is finished, and communicates a dilute black, that is a grey colour, to as much fresh cloth as can be conveniently worked in it.

#### IV. *Method of dying cloth grey.*

THE simple greys, which are all no other than shades of black, are dyed nearly in the same manner as the full blacks; only by using a less proportion of the dying ingredients, or continuing the cloth in the liquor for a shorter time.

A decoction of galls and solution of vitriol being prepared separately, a little of each of them may be put together at once into a copper of water made scalding hot: the liquor becomes black; and cloth, dipt and worked in it, acquires a lighter or deeper grey according to the quantity of the decoction and solution employed: By adding more of the liquors with the next parcel of cloth, and thus proceeding successively, a series of shades may be obtained, from the lightest to the darkest grey. Or the cloth may be first boiled with a proper quantity of galls, and afterwards worked in the same liquor, with the addition of more and more vitriol according to the intended depth of colour. The liquor remaining after

the dying of full black may be used also for the dying of greys.

For the quantities of the ingredients, and the time of the cloths continuance in the liquor, no general rule can be given: as they must depend upon the degree of colour required, the eye only can be the judge. If the colour happens to be too deep, it may be remedied, in some measure, by passing the cloth through hot water mixed with a little decoction of galls, by which a part of the colour will be carried off. A weak solution of alum, tartar, or soap, are in this intention much more effectual, but at the same time very liable, particularly the two first, to exceed in their operation, discharging so much of the colour, unless due care is taken, as to occasion a necessity for re-dying the cloth, which is thus needlessly weakened by the repeated action of the corrosive liquor. The too great deepness of colour may be easily prevented, by examining the cloth from time to time, and taking it out as soon as it has acquired the due shade. It should be immediately washed with a large quantity of water, and the very dark shades should be scoured with soap in the same manner as the full blacks, to fetch out the superfluous colour, or such as is not fixed in the cloth.

The simple greys are dyed from white cloth without any previous ground of blue or other colours. There are also a multitude of compound greys and browns, produced from cloth dyed blue, red, yellow, brown, or of colours compounded of these, by darkening them with the black dye. The distinctions of these various shades, and the manner of hitting any particular one, practice only can teach.



V. *The dying of wool black.*

THE natural grease of wool, of great advantage to it in the warehouse, as being a sure preservative against the moth, must necessarily be removed, before it is attempted to be dyed of any kind of colour: the more perfectly it is cleansed, the better it will be disposed to receive the dye.

The liquor commonly used for the scowering of fleece wool is said to be a mixture of stale urine with twice or thrice its quantity of water. This mixture being made scalding hot, but not boiling, for a boiling heat would felt the wool, or make it run into lumps, so much wool; as the copper will conveniently receive, is dipt in it, and turned from time to time with wooden poles, for a quarter of an hour or more: it is then carried in a large basket into running water, where it is worked by two men, backwards and forwards, one drawing it from under the others pole, till it ceases to render the water turbid. The volatile alkaline salt, produced in urine by putrefaction, unites with the greasy matter into a soapy compound, which, dissolving imperfectly in water, continues to give the turbid appearance till it is totally washed out. The wool is said to lose in this process between one fifth and one fourth of its weight.

The wool thus cleansed is dyed blue, then simmered with galls, and the black dye finished with logwood and vitriol; or for a finer black, which however is seldom wanted on wool; the above method with verdegris may be followed. The manner of procedure is in all respects the same with that for dying woollen cloth; and all the observations, mentioned under the foregoing articles, are equally applicable here. It is only to be added, that the operations, which wool has to undergo, render the pre-  
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venting of harshness of more importance here than in cloth.

#### VI. *Black dye without galls.*

OF the galls, directed in the foregoing processes, a part is commonly omitted in business, and supplied by cheaper astringents, which, being weaker in virtue, are taken in quantity proportionably larger. From the present high price of galls I was induced to try whether this expensive article could not be entirely superseded. I proceeded exactly according to the French process with verdigris, page 411, only instead of the galls taking six times as much oak bark, such as the tanners use: the cloth, well washed with soap after the dye, appeared of a black colour, not indeed quite so beautiful as that dyed in the same manner with galls, yet not a bad one. I tried sumach also, with the same event. It appears therefore, that though no effectual substitute to galls could be found for the purposes of making ink, yet cheaper substances may often be made to suffice in the dying business, where the great consumption of astringent materials renders the reduction of the price of more importance.

In the Swedish Transactions for the year 1753, a fine black is said to be dyed without galls or logwood; the place of both which is supplied by a plant common in Sweden, called there *mjælon* or *mjælon-ris*, which is gathered in autumn while the leaves continue green, and carefully dried that they may retain their green colour. A hundred pounds of woollen cloth are directed to be boiled with sixteen pounds of green vitriol and eight pounds of white tartar, for two hours; and the cloth next day to be rinsed out as after the common alum boiling. A hundred and fifty pounds of the dried *mjælon* cut a little, or a somewhat greater quantity if the plant  
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has been long kept, are boiled in water for two hours; and the *mjælon* being then taken out, a little madder is put into the liquor. The cloth is put in along with the madder, boiled for an hour and a half or an hour and three quarters, and afterwards rinsed in water. This dye is said to be used chiefly for fine cloth, and to give less harshness than the common black.

What the *mjælon* is, we learn from a paper by Linnæus in the same Transactions for the year 1743. He observes, that about a year before, a leaf called *jackaschapuck* was brought into England from North-America, and mixed with tobacco for smoking. Mr. Collinson favoured him with large specimens of it, entitled “the plant Jackaschapuck which is mixed with tobacco, gathered on Churchill river in Hudsons bay.” This plant, he says, was easily known by a Swede, as it grows in Sweden in abundance, on uncultivated gravelly sandy hills. He gives its Swedish names *mjælon*, *mjælon-ris*, *mjælbærs-ris*; and likewise the latin names under which it is described by different botanic writers, from which it is clear, that the *mjælon* is the same with the *uva ursi* that has lately come into esteem in Germany for medicinal use. Some quantity of the *uva ursi* has been brought from Germany, to be tried as a medicine in this country: the plant is raised also in some of our botanic gardens, and if the propagation of it should be found of any importance, it would doubtless thrive on many of our now barren hills.

I have been informed by a foreign correspondent, that the *uva ursi* is said to be used in England for dying black, and that it is imported for this purpose from Hudsons bay. I cannot find that this plant, or any other from Hudsons bay, is known among our dyers or dry-falters; but the two foregoing quotations account sufficiently for the report.

I. made

I made trial of the German *uva ursi* both on white and on blue cloth, exactly according to the Swedish directions; boiling the cloth first with vitriol and tartar, and afterwards with a decoction of the *uva ursi*: on the blue cloth I obtained a tolerably good black, but on the white cloth, as with other astringents, the colour was only a dark brown. I repeated the experiment without the madder, and with a variation in the order of applying the other ingredients, boiling the cloth first in a decoction of the *uva ursi*, and then adding the vitriol and tartar: by this method I obtained, as before, a pretty good black on the blue cloth, but only a brown on the white. I afterwards omitted the tartar also, and did not observe that the want of it occasioned any difference in the colour produced. All the samples dyed brown with *uva ursi* and vitriol, became black on being passed through logwood liquor; but without either logwood or a blue ground, no true blackness could be obtained. A dyer, whom I consulted on this head, made some trials for me, on the *uva ursi*, with the same event; this plant giving no black dye with vitriol alone, any more than the other astringents.

On adding green vitriol to a strong decoction of *uva ursi*, I took notice of a phenomenon which did not happen at all with galls, and which I do not remember to have observed, in so remarkable a degree, with any of the other strong astringents. The liquor, instead of the uniform appearance of the common black mixtures of this kind, looked like a black powder diffused through water; and being written with on paper, the strokes appeared everywhere unequal and specky, as if made with charcoal powder and water, though they were of a deep and durable black where the colouring matter lay thick. This hasty concretion of the black matter from the liquor,  
while

while it renders the *uva ur̄si* entirely unfit for the purposes of making ink, may possibly be of some advantage to it for the black dye; as the largeness of the colouring particles, which concrete in the pores of the cloth, may render them more fixed, so that less of the colouring matter is wasted in the liquor, and less of it can be discharged from the cloth. To this cause may perhaps be ascribed a quality of the *uva ur̄si* dye mentioned by the Swedish author, that the cloth is cleaner than after the other black dyes, or requires less washing to free it from the loose colour.

Among many astringents I have tried, oak wood came the nearest to the *uva ur̄si* in this concretion of the colouring matter. A piece of white flannel was boiled first with oak saw-dust, and afterwards with an addition of vitriol as in the foregoing processes. The liquor, as soon as the vitriol was put in, became bluish-black, though with much less blueness than the cold infusion of oak-dust and vitriol, page 383: some of it being poured off into a glass, it appeared full of powdery matter, which soon settled to the bottom, leaving the liquor of a pale bluish. From the blue colour of this mixture it was hoped, that a black dye might be obtained from it without logwood or a blue ground; and in effect the piece of flannel, though it did not acquire a true black, approached more to blackness than I remember to have observed with other astringents: its colour was a dark grey, without any mixture of blue or brown, like a pure black diluted with a little white. This wood seems therefore to deserve the attention of the dyers: there are grounds to believe that oak saw-dust, or the heart of oak reduced to powder in mills, will be found an astringent of sufficient efficacy, and supply with advantage the place of galls: the oak tree doubtless con-

tains a matter similar to the galls which are produced from it. Possibly by some preparation of the oak-duft, it might be brought nearer to the nature of galls: does not its difference from galls depend on some particular juice, more soluble than the direct astringent matter, and separable by slight infusion in cold water?

VII. *Black dye from a combination of colours.*

IN the first article of this section it has been shewn, that the madder dye, required by the French regulations to be applied upon blue cloth as a ground for black, is rather injurious to the colour than of any real advantage. In the experiments which the determination of that point required, a somewhat unexpected phenomenon occurred, an account of which was reserved for this place. A piece of deep blue cloth was boiled in water with alum and tartar, as customary for preparing cloth to receive the madder dye. The cloth being taken out and squeezed a little, some powdered madder was boiled in water, in such quantity as to communicate a dark red colour to the liquor. The cloth, still moist, was put into this decoction, and a boiling heat continued about half an hour. Being then taken out and washed with soap, it looked of a very dark colour, such as any person would call a black, though not a fine black. Thus we have a kind of black dye, very durable, without any vitriol or other preparation of iron, from a combination of the blue dye with the madder red.

This effect of madder upon blue cloth is well known to the dyers, among whom the colour hence produced is called madder-black. Our black cloths for home consumption are all dyed with vitriol and astringents, either on a ground of woad, which makes the true black, or with an addition of logwood only, in which case the  
colour

colour being more perishable is called false: but the black baize, which we export to Spain and Portugal, are dyed chiefly of the madder black, a species of blackness which there, it seems, is in estimation.

If, instead of madder, the purer red of cochineal be applied on blue cloth, the colour hence resulting, is not at all black, but purple. Cochineal, independently of its too great expensiveness for purposes of this kind, is too bright a colour to have a place in the composition of blackness: to change the purple into a colour approaching to black, the addition of other colours is necessary, for it is not to be expected that a mixture of simple blue and red should produce a black (see page 355.) But madder is both a dark and a compound colour, in which an admixture of brown or tawny with the red is very manifest. If the madder be slightly infused in warm water, and afterwards boiled in a fresh quantity of water, the first liquor will appear of a pretty good red colour, the other remarkably more dark and brownish. Hence for dyeing a good madder red, a boiling heat should be avoided; but for the black dye the madder ought to be well boiled, that the brown as well as the red parts may be extracted.

The madder black might probably be deepened by making it still more compounded, as particularly by the addition of a dark yellow; but any improvement of this kind would be of little advantage to the dyer, who finding the dye already too expensive, endeavours to imitate it with the cheaper vitriolic black. And indeed, independently of considerations of this kind, he is here rather confined to a particular shade or species of colour, which fashion has brought into esteem, than solicitous about deepening the dye or making it more perfectly black.

## S E C T. VIII.

*Of the dying of silk black.*

**R**AW silk, in the state in which it is wound off from the cocons, has a harshness which renders it unfit for being spun, and for the most part a pretty deep yellowish or reddish-yellow colour, from both which it is cleansed, by boiling it with soap, and afterwards thoroughly washing it with soft water: when woven, it is again washed with soap, to free it from the greasiness it may have contracted, which would occasion it to be spotted in dying. The silk loses in the boiling generally about a fourth part of its weight: this proportion is assigned by the writers on dying, and on enquiry among the workmen, I find it universally allowed to be the nearest calculation. In being dyed black, this loss is fully made up, the weight of the dyed silk being commonly even greater than that of the raw silk. There is no dye which adds so much to the weight as black: the increase is considerable in woollen as well as in silk, though most taken notice of in the latter on account of its great price.

Mr. Macquer observes, in his *art de la teinture en soie*, published in 1763, that the finest oil soap is required for this cleansing of silk; that there is nothing saved by using the inferior kinds, a proportionably greater quantity of them being necessary; that some sorts of soap curdle with the matter which they extract from the silk, into a substance almost of the consistence of wax; that those, which are made with animal fats, prevent the silk from having the proper dryness and lustre, and dispose it to grow reddish in keeping; that even the best soaps are accompanied with some imperfections in this respect, and that the superiority in lustre, of the Chinese silks to the European,



European, is owing to the former being cleaned without any soap. In a French dissertation on this subject, to which a premium was adjudged by the academy of Lyons, in 1761, the ill qualities of soap are attributed to its oil, and a solution of simple alkaline salt, made so dilute as not to corrode the silk itself, is recommended in its place: the salt of soude or bariglia, as being the mildest of the alkaline salts, is for this purpose justly preferred to the common more corrosive alcalies. Alkaline salts, either in their pure state or made into soap with oils, are the only known menstrua that extract the matter which gives harshness and colour to raw silk.

What this matter is, has not been sufficiently examined. As it is not dissolved by water, spirit of wine, or by acids so far diluted as not to destroy the silk itself, Mr. Macquer supposes it to be either a concrete oily substance, whose oil is of the nature of expressed oils; or a compound of oily and gummy matter, so proportioned and combined, as to protect one another from the action of their respective dissolvents. Whatever can be said of the composition of this matter, may perhaps be said equally of that of silk itself, which is not an organised fibre like wool, but is in its whole substance a concrete animal juice: naturalists observe, that on opening the silk-worm at a proper season, the yellow silky juice may be readily distinguished, and drawn out into fine flexible filaments. Alkaline salts, which when diluted with water, or sheathed with oil, to a certain degree, are found the proper menstrua of the harsh and tinging part of raw silk, in a purer or less dilute state, or by longer boiling, dissolve also the matter on which the tenacity or cohesion of the silk depends. Some of the spun silk called in the shops raw silk, but which has been boiled with soap previous to the spinning, and suffered the diminution of weight

weight before-mentioned, on being boiled in a solution of alkaline salt, received a further diminution of two-thirds: another quantity of the same silk being boiled longer with the alkali, about four-fifths of its weight were taken up by the liquor, which became reddish, and the remaining fifth was an incoherent friable mass, not ill resembling *papier maché*. It should seem from these experiments, that even the common process of cleansing silk, in which a fourth of its weight is dissolved, cannot be entirely innocent, but must contribute in some degree to diminish the strength of the silk; and accordingly I find it allowed by the workmen, that a thread of silk boiled is not so strong as when raw. Some further experiments of the effects of different substances on raw silk are now in hand: if any thing of importance results from them, they shall be communicated in the appendix to this volume.

Silk is rarely or never dyed of a blue as a preparatory ground for the black dye. The regulations of the French silk dyers expressly order its being dyed directly from white to black, and this, as I am informed, is the general practice among us, though some report that the German silk dyers give a brown ground for their black silks, by boiling them with the root or bark of the walnut-tree. The only reason I have heard assigned for the omission of the blue ground on silk is, its adding to the expence of a process, which is otherwise, as commonly managed, considerably more expensive and troublesome than the dying of woollen.

Mr. Macquer reckons black a difficult colour to dye on silk: and indeed, if all the circumstances, and materials, of the complex process, which he describes as being followed in many of the good dye-houses of France, were necessary for succeeding in the colour, a multitude of  
 trials

trials must undoubtedly have been made, before success could have been attained to. But experience has abundantly shewn that the case is otherwise; that the fenugreek seed, fleawort seed, cummin seed, coloquintida, cocculus indus, buckthorn berries, agaric, nitre, sal ammoniac, sal gem, litharge, antimony, black-lead, orpiment, corrosive sublimate, white arsenic, realgar, several of which are added again and again in different parts of the operation, are entirely inessential to the dye, and contribute rather to do harm than good. Mr. Macquer himself suspects that some of these ingredients are unnecessary; and he has subjoined a process followed in the manufacturies of Tours and Gênes, from which we may fairly conclude that they are all so; and that a fine black may be dyed on silk in as simple a method as on wool or woollen cloth, the silk requiring only a greater quantity of the ingredients, and a greater number of dippings in the black liquor. The process is as follows.

The silk, washed with soap as above directed, is steeped in a decoction of one third its weight of Aleppo or blue galls, or half its weight of the weaker white galls of Sicily and Romania, and afterwards washed with water: every twelve ounces are reduced by the cleansing to nine, which ought to be increased by the galling to eleven and not more. The dying liquor, for a hundred pounds of silk, is prepared by boiling twenty pounds of galls in a sufficient quantity of water (about a hundred and twenty six gallons) and adding to this decoction, after being settled and drawn off from the sediment, two pounds and a half of English vitriol, twelve pounds of iron filings, and twenty pounds of the gum of the cherry or plum tree: that the gum may dissolve the more readily, it is put into a large copper cullender, immersed in the hot liquor, and stirred and worked from time to time with a  
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wooden rod till it is all passed through. This mixture is kept for six or seven days or more, a circumstance supposed to be necessary to its perfection; and being then made as hot as the hand can bear, fresh parcels of the galled silk are dipt in it successively, and kept in about ten minutes each; and all of them, after being aired, are dipt over again, several times, with the addition of more vitriol and iron filings, till they have acquired the requisite blackness, after which they are well washed in water. It may be observed that while five or six pounds of galls are sufficient for a hundred pounds of wool, upwards of fifty pounds of galls are here allowed to the same quantity of silk; and that logwood, an essential ingredient in the black dye on white woollen, is not at all required for silk. The quantity of vitriol is not specified.

I tried this process in small, with the exact proportions of each of the articles above set down; and by adding more and more of the vitriol, and repeating the dippings thirty times or more, I obtained at last a good black. After less than half this number of dippings, the silk appeared of a beautiful black when taken out of the liquor, but by washing it became pale, and in drying it turned always paler. The quantity of vitriol used in all was about eight times that prescribed above to be added at one time, or one fifth of the weight of the silk; but the iron filings put in at first remaining undissolved, it was not thought needful to add any more of this ingredient. I repeated the operation without any iron filings, and could not observe that the two blacks differed from one another. I tried it also without the gum: there was here a very considerable difference in the silk as taken out of the dye, that which had been dyed with gum having a fine glossiness, which the other wanted: the subsequent

sequent washing, however, destroyed, as was expected, the glossiness of the gummed silk, and reduced them both to the same appearance, so that the gum seemed to be of no manner of advantage: perhaps it is rather of disservice than otherwise, by thickening the liquor, and making it more difficultly penetrate into the silk, in the same manner as it renders ink indisposed to sink into paper. I likewise dyed some silk by the two processes described in the foregoing section for woollen cloth, (page 410 and 411) and obtained by both of them a rusty black upon white silk, and a very good black upon blue: so deep a blue as is allowed for the true black on fine woollen cloth, did not appear necessary for silk; a very slight blue ground being here sufficient to make the black both deep and durable.

It should seem therefore that silk is not, in any particular manner, more averse than wool to the receiving of the black dye; and that a good black may be dyed on silk, with the same materials, in the same method, and with the same dispatch, as on wool and woollen cloth; of which a further confirmation will appear at the end of the following section. It may be observed, that though silk takes a sufficiently good black dye from the method practised for fine woollens, yet woollen does not take a black from the process that has been appropriated to silk; for some pieces of white flannel having been put in along with the white silk in one of the trials of the French process above described, the flannels became only brown, while the silk turned out black. Though a black may be dyed on white silk without logwood or verdegris, the first of which is a necessary material for white woollen; yet an addition of both contributes not a little to improve the colour on one as well as on the other.

## S E C T. IX.

*The dying of hats black.*

**T**HE Instructions of Mr. Colbert direct hats to be first strongly galled, by boiling them a long time in a decoction of galls with a little logwood, that the dye may penetrate the better into their substance; after which a proper quantity of vitriol and decoction of logwood, with a little verdegris, are added, and the hats continued in this mixture also for a considerable time. They are afterwards to be infused in a fresh liquor of logwood, galls, vitriol, and verdegris; and where the hats are of great price, or of a hair which difficultly takes the dye, the same process is to be repeated a third time. For obtaining a colour of the utmost perfection, the hair or wool is ordered to be dyed blue previously to its being formed into hats. The present practice is more compendious, and affords, as we may daily see, a very good black. The method of our hatters, as I have been informed, does not differ materially from that of the French, described in the *encyclopedis*, which is as follows.

An hundred pounds of logwood, twelve pounds of gum, and six pounds of galls, are boiled in a proper quantity of water, for some hours; after which, about six pounds of verdegris and ten of green vitriol are added, and the liquor kept just simmering, or of a heat a little below boiling. Ten or twelve dozen of hats are immediately put in, each on its block, and kept down by cross-bars for about an hour and a half: they are then taken out and aired, and the same number of others put in their room. The two sets of hats are thus dipt and aired alternately, eight times each; the liquor being refreshed each time  
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with more of the ingredients but in less quantity than at first.

This process affords a very good black on woollen and silk stuffs as well as on hats, as we may see in the small pieces of both kinds which are sometimes dyed by the hatters. The workmen lay great stress upon the verdigris, and affirm that they cannot dye a hat black without it: it were to be wished that the use of this ingredient was more common in the other branches of the black dye; for the hatters dye, both on silk and woollen, is reckoned a finer black, than what is commonly produced by the woollen or the silk dyer.

#### S E C T. X.

##### *Of the dying of linen and cotton black.*

**T**HE black vitriolic dye, though very durable on the substances hitherto mentioned, is perishable on linen and cotton. Pieces of linen and cotton cloth, and skins of thread, boiled first with galls, and afterwards infused and dipt repeatedly in a decoction of logwood with vitriol, received a good black colour; but both the brownish stain which the galls communicate, and the blackness superinduced by the vitriol, were in great measure discharged by washing with soap; even the rusty colour, which the vitriol of iron gives by itself, seeming, in this way of application, to be less fixed than if it had been employed without the galls. Steeping the linen for a month, previous to the dye, with galls, and with oak bark, by which method fishing nets receive from the astringents a pretty durable stain, was here of no service, the black dye proving equally perishable.

The dyers of thread follow a process somewhat different from the above. They first steep the thread in alum  
K k k 2 water

water for several days; and then dip it repeatedly in the dying liquor, cold, or only lukewarm. The dying liquor consists of the irony and astringent matters mixed together; and in the room of, or along with, vitriol, they use either filings of iron, or the muddy matter by some called slipp, found in the troughs of grindstones where iron tools are ground. The woollen dyers are sometimes required to dye certain pieces of linen black, and in such cases they practise a method of the same kind; steeping the piece first in alum water for two or three days, and then dying it in their mixed black liquor. By this means the colour is made to hold somewhat better; but how perishable it still is, we may see in all black thread.

As the stain produced by solutions of iron is very fixed on linen and cotton; and as the perishableness of the black dye seemed to be owing to the astringent matter of the galls not sufficiently penetrating or uniting with the vegetable fibre, and therefore too easily coming off, and carrying the superinduced vitriol with it; I boiled pieces of linen and cotton, first in solution of vitriol, and afterwards with galls, hoping that the vitriol, fixing itself first in the cloth, would make the astringent matter applied upon it likewise fixed. But the event was otherwise: the colour did not prove so black as when the contrary method of application was followed, and the blackness was rather more destructible.

The colour of indigo and madder being very durable on linen, it was hoped that a ground of these might contribute to fix the black. I therefore made trial of sundry pieces of red and blue linen, dying them black by the methods already described. They appeared to have no advantage above those which had been dyed directly from white: the black was as easily washed out, the blue  
pieces



pieces remaining nearly of their original colour, and the red ones a little darker coloured than at first.

After many other fruitless attempts, with different solutions of iron and different intermedia, no probability of success appeared to remain, unless the vegetable subject could be changed as it were in its nature, or impregnated with an animal principle. Accordingly I boiled linen and cotton, previous to the galling, with weak solutions of animal glues, but the success was no better than before.

In the fourth volume, lately published, of the Memoirs of the correspondents of the French Academy of Sciences, M. l'Abbé Mazéas gives a curious dissertation on the red printed cottons of the East-Indies; in which he describes a method, practised by the Indians, of impregnating their cotton with animal matter in order to its receiving a red stain. A ley is made from the ashes of a certain kind of wood, and with this is mixed some sheeps dung and a quantity of the oil of sesamum, in want of which oil, they use hogs lard: these ingredients stirred together, are said to unite into a milky liquid. The cotton is steeped in this liquor during the night, and exposed to the hottest sun during the day for a fortnight. The author above-mentioned says he tried this process with the common expressed oils, without success; but that with hogs lard it succeeded perfectly.

On reading the Abbé Mazéas's paper, I immediately set about trying, what effect a like preparation would have in regard to the black dye. Here a considerable difficulty occurred in making the mixture; for with a strong ley of wood ashes, or with a solution of purified alkaline salt, the lard could not be made at all to unite by stirring, or even by boiling; the liquor acquired no milkiness, and the lard floated distinct on the surface;  
and

and indeed it was not expected, that a perfect union of this ingredient could be procured without the use of the caustic ley of the soap-boilers prepared with quicklime. The intention, however, being only to obtain a soap made with animal fat, and the common soft soap being such a one; I mixed soft soap and sheeps dung well together, three parts of the former to two of the latter, and diluted the mixture with warm water. Some pieces of linen and cotton cloths, and some skins of linen thread, were steeped in this liquid every night, and hung out in the day-time, not indeed in a hot sun, but in all that the month of december last afforded. The subjects were then all dyed black, by the second of the processes described for woollen cloth, page 411; and some of the same kind unprepared, were put into the dye along with them. All the pieces being taken out and washed, the prepared ones appeared to hold their colour better than the unprepared, though not in such a degree as to make the process interesting to the workman. From this shew of success however, in an unfavourable season, the experiment seems worthy of being tried again in more advantageous circumstances.

We have seen in the second section, that linen and cotton are stained of a lasting black colour by certain vegetable juices; and that these juices might probably be obtained in quantity, if not in our own country, yet in certain parts of the British dominions, some of the trees which afford them being natives of our American settlements. Till this branch of vegetable curation shall be established, the British artist can receive little benefit from knowing the materials, with which the deep black stain on the Indian cottons is said to be fixed.

We have seen also, in page 420, that a black colour, or a colour approaching to blackness, may be produced  
on

on woollen cloth, from a combination of two other dyes, viz. by applying a full madder red upon a deep blue ground. Both the blue and the madder red can be fixed upon linen as well as on woollen; and accordingly I tried compounding them on linen in different ways, sometimes applying the red upon the blue, and sometimes the blue upon the red. In several of these experiments the linen, as it came out of the dye, appeared of a good black colour, but on washing it, so much of the colour was discharged, that only a kind of dark purplish remained.

Some printed linens and cottons have a durable black stain, which, as I am assured by a skilful and ingenious artist, is made with madder and a solution of iron. A quantity of iron is put into four strong beer; and to promote the dissolution of the metal, the whole is occasionally well stirred, the liquor at times drawn off, the rust beaten off from the iron, and the liquor poured on again: a length of time is required for making the impregnation perfect, the solution being reckoned unfit for use till it has stood at least a twelvemonth. This solution stains linen yellow, and of different shades of buff colour, and is the only known material by which these colours can be fixed on linen. The cloth, stained deep with the iron liquor, being afterwards boiled with madder, without any other addition, becomes of the dark colour which we see on printed linens and cottons, which, if not a perfect black, has a very near resemblance to it. It is submitted to the consideration of those whom it may concern, whether this fixt colour would not be preferable, on linen thread, to the perishable black with which thread has hitherto been dyed. It is probable, that even a better black might thus be dyed on thread, than that which the printer on linen produces: for in this last business, while some parts of the linen are stained deep with the iron liquor, in order to their  
being

being made black; others are stained paler, with the same liquor diluted with water, for making purple; and others, designed to be red, are prepared with a solution of alum and sugar of lead: all these colours are dyed in one and the same copper of madder, with a heat a little below boiling: a boiling heat would give a dark tawney or blackish hue to the red, and therefore in this process must necessarily be avoided; but for the same reason it would contribute to deepen the black, and therefore ought always to be called in aid where thread, or entire pieces of linen or cotton, are to be dyed of this colour.

## S E C T. XI.

*The staining of Wood, Ivory, Stones, &c. black.*

I. *Wood.*

**T**HE staining of wood black, for picture frames, &c. depends on the same principle with the black dye in the foregoing sections. For a deep black, the wood is brushed over four or five times with a warm decoction of logwood, and afterwards as often with a decoction of galls, being suffered to dry thoroughly between the several applications of the liquors: thus prepared, it receives a fine deep black colour, from being washed over with solution of vitriol; in the room of which, some use a solution of iron in vinegar, keeping the vinegar for this purpose upon a quantity of the filings of the metal, and pouring off a little as it is wanted. A pretty good black is obtained also, more expeditiously, by brushing over the wood, first with the logwood liquor, and afterwards with common ink.

Plumier, in his *Art de tournir*, directs the wood to be previously washed twice with the second parting water of  
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the refiners (*aqua secunda forti separatoria, eau forte seconde*) by which I suppose he means, not aquafortis itself, but the solution of copper in aquafortis remaining after the silver has been precipitated. Washing with aquafortis was found to prevent the production of any black colour on the application of vitriol and astringents, as indeed was expected, this acid liquor destroying the colour of ink already made: a saturated solution of copper in aquafortis appeared to be of no immediate injury, but it appeared also to be of no advantage.

## II. *Ivory, bone, horn, &c.*

IVORY, bone, horn, and other solid parts of animals, may be stained black in the same manner as wood. They likewise receive a deep black stain from solution of silver, which should be diluted with water to such a degree, as not sensibly to corrode the subject, and applied two or three times, if necessary, at considerable intervals, the matter being exposed as much as possible to the sun, to hasten the appearance and deepening of the colour: see page 350. Hair also, made perfectly clean, and moistened with the same solution, is changed from a red, grey, or other disagreeable colours, to a brown or deep black: the liquids commonly sold under the name of hair-waters are at bottom no more than solutions of silver, diluted largely with water, with the addition perhaps of other ingredients, which contribute nothing to their efficacy. The solution should be fully saturated with the silver, that there may be no more acid in it than is necessary for holding the metal dissolved; and besides dilution with water, it will be proper to add a little rectified spirit of wine for the further dulcification of the acid. It must be observed, that for diluting the solution, distilled water or pure rain water must always be used; the common spring waters turning

it milky, and precipitating a part of the dissolved silver. It is to be observed also, that if the liquor touches the skin, it has the same effect thereon as on the matter to be stained, changing the part moistened with it to an indelible black.

### III. *Marble.*

IT is difficult to introduce into marble a true black colour. Solution of silver sinks deep into the stone, sometimes an inch or more; but the colour it communicates, at first reddish or purplish, deepens only to a brown. Mr. du Fay, in the Memoirs of the French Academy for the years 1728 and 1732, gives two methods of staining marble of a blue colour, approaching more or less to black according to its deepness, and not ill resembling those which are naturally found in some marbles: one is with essential oil of thyme digested in volatile spirit of sal ammoniac, the other with tincture of archel. When the oil of thyme is digested with the volatile spirit, it becomes first yellow, then red, then violet, and at last of a deep blue. In six weeks digestion it had acquired a pale blue, and in this state gave little colour to marble: after standing for six months, it was deepened almost to a black blue, and being now applied on warm marble, gave the stain desired.

With regard to archel, a tincture of it in water is applied on cold marble, and renewed as it evaporates, till the colour is sufficiently deep. Though the colour of archel is very perishable on cloth, yet in marble it appears to be more durable. Mr. du Fay says he saw pieces of marble stained with it, which in two years were not sensibly changed. The colour however, though made very deep, is far from being a true black, being rather a dark purplish blue.

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The porous marbles, which admit water to sink into them, I have stained of a full black colour with common ink; either by applying on the warm marble an ink already made, or by the alternate application of astringent liquors and solutions of iron. With the more compact marbles, this did not succeed, though they were heated so far as to make the liquors boil upon them: in some parts the colouring matter scarcely penetrated at all; and where it did sink a little into the stone, it was so dilute as to appear only purplish. The spirituous tinctures, described in page 388, made without the mastich, seemed to penetrate better than the watery infusions.

On marbles which would not receive the inky matter, I tried the alternate application of solutions of lead and of sulphureous solutions, applying sometimes the one first, and sometimes the other; but could not find that they produced in the stone any degree of the black or dark colour which they do on paper. By solution of copper, managed as at the end of the following article, and by a solution of the metallic part of cobalt in aqua regia, employed in the same manner, the most compact pieces were stained black; though this process requires too great a heat to be practised on marble without danger of injuring the stone. The colour which solutions of gold communicate to marble, in its deep shades obtained by repeated applications of the solution, approaches very near to black.

#### IV. *Agate, &c.*

SEVERAL of the hard stones, which strike fire with steel, receive a dark stain inclining to black from solution of silver. Mr. du Fay relates, in the French Memoirs for 1728, that to chalcedony, this solution gave a reddish brown colour; to oriental agate, a blacker stain; to an agate spotted yellow, a purple; to the jade stone, a pale

brown; to the common emerald, an opaque black; to the white parts of the common granite, a violet unequally deep; to serpentine stone, an olive colour; while the much softer flates, talcs, and amianthus received from it no colour at all. The experiments formerly mentioned, page 350, afford room to suspect, that the solution of silver stains stones only in virtue of their containing a calcareous earth, or such an earth as the acid is capable of dissolving: if this be the case, there is little wonder, that some of the hard stones should be stained, and some of the soft unaffected by it.

Among the hard stones that have been tried, the agates seem to be those which are acted upon most readily: they are those also which have ofteneft been attempted to be stained. The solution should be made in strong aquafortis or spirit of nitre, and fully satiated with the metal. The stone, after the fluid is applied, should be exposed to the sun for two days or more; and if, when dry, it be removed into a moist place, and afterwards exposed again to the sun, the production of the colour will be the more speedy. After the stone has acquired the full colour which the first quantity of the solution can communicate, it may be moistened with more, and this repeated two or three times, by which the colour will be deepened, and made to penetrate further: Mr. du Fay found that an agate about a sixth part of an inch in thickness, by applying the solution on both sides, may be stained throughout its whole substance. The tincture, however, is rarely uniform, on these or other stones; most of them having veins, which, though indiscernable in the natural stone, are in this process made apparent, being more easily or more difficultly penetrable than the rest of the mass, and sometimes forming not inelegant varieties in the stained stone.

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Mr. du Fay observes, that though stones may without much difficulty be stained by solution of silver, yet it is scarcely possible to form very neat designs on them, on account of the spreading of the liquid; and that this imperfection appears to be the less, according as the solution is the more saturated, so as to dry or crystallize the more speedily. An easy method of obviating this inconvenience is suggested by the practice of the engraver; for the means, by which he confines the aquafortis on his copper plates to the minutest strokes, would doubtless answer the same intention here. The surface of the stone being coated with a proper tenacious substance which the acid cannot act upon, as the composition called etching wax, which consists of resinous substances melted with wax or boiled with oil to a due consistence, and the drawing being made on this ground, so that each stroke may reach down to the stone, it may be presumed that the solution of silver, afterwards applied, will nowhere spread further than the parts thus laid bare..

The stones thus coloured by art differ from the natural in two remarkable properties of the colouring matter. The natural colours resist moderate heat, by which the artificial are in great part destroyed. The natural stones, steeped for several hours in aquafortis, suffer no apparent change; whilst those, which have been coloured by art, almost entirely lose their colour. It is observable that the colour destroyed by aquafortis is restored again by exposing the stone to the sun: but that the colour destroyed by fire cannot be recovered without a fresh application of the colouring solution.

There is another method of staining stones, of a colour more truly black than that which the solution of silver communicates to most of them, and with this further difference, that the colour being produced by fire, I have  
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not found that either moderate fire or aquafortis will destroy it. Pieces of different stones, marbles, pebbles, flint, &c. were washed over with a saturated solution of copper made in aquafortis: when dry they were put into a crucible, and kept for a little time in a fire just sufficient to make the vessel almost red hot. All of them were stained, in the parts which had been moistened with the solution, of a black colour, durable and pretty deep, though it had penetrated only a very little way into the substance of the stones.

When the smooth surface of an agate, or other stones not dissolvable in aquafortis, is moistened with the copper solution; if a small iron nail be set upright on its head in the middle, the iron absorbs the acid from the copper, and the copper, now separating from the fluid, shoots into fine ramifications like the branches of trees or shrubs, generally of a very elegant appearance. If the nail be then removed, and the corroded iron carefully washed off by dipping the stone in water, the vegetations may be changed by heat to the same black colour as the simple solution of copper in the foregoing experiments, so as greatly to resemble the figures naturally found in certain stones, as that called the Mocho stone. The colour is not indeed fixed on the stone, like that resulting from the solution of copper alone; but a plate of crystal laid over it in the manner of a doublet, conceals this imperfection. The only difficulty in this operation consists in the washing, in which great dexterity is requisite, to separate the corroded iron, which would give a rusty stain, without washing off or disordering the fine vegetations of the copper.

S E C T.

## S E C T. XII.

*Black glass and enamel.*

**T**H E R E is a species of blackness, as we have formerly seen, which results, in certain circumstances, from the simple deepness or concentration of other colours. Thus many vegetable juices and infusions, yellow, reddish, blue, &c. on being evaporated to the thick consistence of an extract, look black; and these black masses, when spread thin or diluted with water, exhibit again the original colours of the liquors. Something of the same kind seems to happen in glass and enamel. Smalt or zaffre, which in a certain proportion give a blue colour to vitreous bodies, if employed in a larger quantity make them black. Manganese, which in a little quantity gives a purplish tinge, in a large one gives a black. Preparations of iron, whose colour in glass, in a dilute state, is sometimes yellow and sometimes greenish or bluish, are always of a dark brown or black when the glass is over-dosed with them: hence many of the ferruginous earths and stones melt into a black glass, as the coloured clays, several slates, and the stone called whynn stone, with which some of the streets of London have been lately paved. Black glasses or enamels made on this principle have however, like the concentrated vegetable liquids, one imperfection; that though of a deep black colour when in masses of any considerable thickness, yet when spread thin they always betray some of the original colour, or of the particular hue which they would have if the colouring matter was in less quantity. The most perfect black is obtained by adding a mixture of two or more of the above darkening materials: instead of taking colourless glass or enamel for the basis, it will be of advantage to use fragments of different

ferent coloured pieces; and compositions which have been spoilt, in trying to tinge them of other colours, answer as well for this purpose as any.

The common black glass, of which beads are made for necklaces, &c. is coloured, as I am informed, with manganese only; hence when powdered it looks of a dirty purple colour. The manganese perhaps increases the fusibility of the glass, for an ingenious friend observes, that in making impressions in different kinds of glass, he has found this black sort to be by far the most fusible of any. That there is a strong action between the manganese and the glass may be presumed from the great effervescence which happens on melting them together. One part of manganese is sufficient to give a black colour to near twenty of glass.

The enamellers require a black more perfect than that which manganese alone can produce, and employ, as I am informed by an experienced artist, a mixture of manganese, zaffre, and scales of iron. These ingredients may be mixed together in equal quantities, and one part of the mixture added to fifteen or twenty of the basis of enamels; which basis is prepared by calcining a mixture of about equal parts of lead and tin, and melting this calx with equal its quantity of fritt or powdered glass.

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## VII. HISTORY OF PLATINA.

**I**N the beginning of the year 1749, there was brought into England, from Jamaica, a quantity of a white metallic substance in grains, scarcely known before to Europe, said to be the produce of the Spanish West-Indies, and there called *Platina*, *Platina di Pinto*, or *del Pinto*, and *Juan blanco*.

The name *Platina* seems to be a diminutive of *plata*, silver, and consequently to express the most obvious appearance of this body, that of a silver-coloured metal in small grains. From its being called *platina of Pinto*, it may be supposed that Pinto is the name of some particular spot or district which affords it: I have not met with this name in any accounts I have seen of Spanish America, but Mr. Cronstedt, in an essay for a new mineral System, lately published in Sweden, speaking of *platina* in the course of his system, calls the place it is brought from Rio di Pinto. Its other appellation, *Juan blanco*, arose perhaps from some frauds which had been practised with it, from the difficulty of separating the gold naturally intermingled with it, or from its refractoriness in the hands of the workman; for as in our own country a dusky coloured mock-ore, that is, a mineral which has the appearance of a metallic ore, but does not in the usual ways of trial yield any metal, is commonly called *black-jack*; the Spaniards may in like manner have given the name *white jack*, *white rogue*, *white mock metal*, to this singular metallic body, which though of the true metallic aspect and weight, and in some degree malleable, had eluded all their attempts for smelting or running it down.

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Mr. Charles Wood, assayer-master in Jamaica, had seen some platina in that island eight or nine years before it was imported here. He says it was brought thither from Carthagena; that the Spaniards have a way of casting it into different kinds of toys; that these toys are very common in the Spanish West-Indies; that some pounds of the metal were bought at Carthagena for less than an equal weight of silver, and that it was formerly sold at a much lower price. He gave some specimens of it to Dr. Brownrigg, who in 1750 presented them to the Royal Society.

The seeming inconsistency between this account and the foregoing, in regard to the fusibility of platina, was easily reconciled by examining Mr. Woods specimens. Some of them were of the true platina in grains, called native or mineral platina, which we have very good grounds to believe the Spaniards have never been able to melt. But there was one of an actual cast metal, a piece of the pommel of a sword. A part of this was sent to me for trial; and I was afterwards favoured with a large piece of an ingot of the same kind of metal, by the right honourable the earl of Macclesfield, the late worthy president of the Royal Society. This metal was found to melt with great ease, and was apparently not true platina, but a composition of it with some other metallic bodies. As the compound metal has been frequently confounded with the platina itself, and called by the same name, some considerable errors have hence arisen in regard to the properties of the platina, which will be occasionally taken notice of in the course of our experiments. It is sufficient here to have observed, that the cast metal differs materially from the true platina which makes the object of the present history.

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The platina soon engaged the attention both of philosophers and metallurgists, on account of its agreement, in some remarkable particulars, with gold. From this relation to gold, it was called by some *white gold*. Hence also many people were induced to think, that it was at bottom no other than gold, disguised by a coat of some extraneous matter; and it was hoped that means might be discovered of divesting it of this coat, and laying bare the gold which it was supposed to conceal. But the more it was examined, the more did this notion seem improbable; and the more grounds were found for believing, that platina is a metal of a peculiar kind, distinct in nature from gold, as well as from the other metals, though endowed with such properties, as had hitherto been supposed to be characteristic of gold, or to be possessed by gold alone; inasmuch that this new metal was reported to have been sometimes fraudulently mixed with gold, in considerable quantity, without being either separable, or distinguishable, by any of the common methods in which gold is assayed or refined.

A full examination of such a body appeared of the utmost importance, as regarding not only the discovery of the various properties of the platina itself, an object sufficiently interesting, but likewise, what is much more so, the preventing the abuses which it was liable to give occasion to, and the securing the fineness and value of the precious metal; so that if the platina should not be rendered an useful commodity, it might at least be no longer a dangerous one.

I had begun this examination in the year 1749, but could not then procure enough of the platina for carrying the experiments to such a length as I aimed at; for a metal so extraordinary, entirely new, at least to this part of the world, of which only a few general properties were

known, and these but partially and imperfectly, deserved to be submitted to all the kinds of operations that are practised on the other metals, and to all the agents by which other metals are found to be affected. In the beginning of the year 1754, his excellency general Wall, at that time ambassador from Spain, enabled me to proceed in the experiments, by sending me about an hundred ounces; and I was afterwards favoured with considerable quantities more by some other gentlemen. The most ingenious and experienced chemists in Europe, as soon as they could obtain any of the new metal, entered into the same pursuits; and several of these enquiries have from time to time been made publick.

The first publication I have seen on this subject is that of Mr. Wood, in the 44th volume of the Philosophical Transactions, for the years 1749 and 1750. To the historical observations, of which an abstract has been given above, Mr. Wood subjoins a few experiments, made partly, as may be presumed from their event, on the true platina in grains, and partly on the cast metal; one of which experiments, the cupellation of the cast metal with lead, was afterwards repeated, more circumspcctly, by Dr. Brownrigg.

In the 48th volume of the Transactions, part 2d, for the year 1754, is inserted an account of the principal experiments which had been then made on the platina by me. They are divided into four papers, which are followed in the next volume by two papers more.

On the publication of the first four, I was informed that Mr. Scheffer also had given an examination of this metal in the *Handlingar* of the Swedish academy of sciences for the year 1752. Those books being difficultly procurable in this country, and written in a language which I did not understand, it was some time before I could.



could avail myself of his enquiries, which I found to be curious and interesting, and carried, though not so far as could be wished, yet much further than could have been expected, considering that for his principal experiments he had only a hundred grains of the crude mineral, from which he could pick out but forty grains of the platina to work upon, and that he had no previous notice of its possessing any remarkable properties, but looked upon it at first as being only an iron mineral; he afterwards indeed obtained some more, but it was only such another little quantity. These experiments were made by the encouragement of Mr. assessor Rudenschœld, who has lately informed me, in a letter from Stockholm, that he brought the platina from Spain in the year 1745, nearly four years before it was known in England. In one of the following volumes of the Swedish *Handlingar*, there is another paper by the same gentleman, containing observations on some parts of mine, concerning the specific gravities of mixtures of platina with other metallic bodies.

A French translation of all the papers above-mentioned, except the last of Mr Scheffers and the two last of mine, which had not come to the translators knowledge, was published at Paris in 1758, under the title of *la platine, l'or blanc, ou l'huitieme métal*: to this treatise is added an extract of a letter from Venice, relating to what may be called the alchemical history of platina, not containing any new facts, but some reflections drawn from mine.

Professor Marggraf, of the academy of sciences at Berlin, having obtained a quantity of platina from London, made a large set of experiments upon it, repeating and further prosecuting several of mine, and adding many new ones. These appeared first in a French translation, among the *Mémoires* of the Berlin academy for the year 1757, printed in 1759: they have since been published,

more

more correctly, in the original German, in the first volume of a collection of his chemical writings, the continuation of which is earnestly wished for.

In the *Mémoires* of the academy of Paris for 1758, printed in 1763, there is a paper on this metal by Mr. Macquer and Mr. Baumé conjointly; who, besides repeating and varying some of my experiments, and drawing from them some new consequences, have exposed the platina to an agent which the other enquirers have not had opportunities of doing, a large burning concave. Their platina, in quantity a pound, was sent to them from Madrid.

The foregoing are the only writers I know of, who have treated expressly and experimentally on platina. Some others have mentioned it occasionally, as particularly Mr. Cronstedt and Mr. Vogel, in their new mineral systems. The former has in general given a very just account of it; but the latter appears to me to be a little mistaken in some points, which will be further taken notice of in their places.

Since the publication of my experiments in the *Transactions*, I have at times been adding others, and endeavouring to ascertain some properties of platina which before had been too slightly examined. Nothing now is so much wanted, in regard to this extraordinary metal, as a regular history of what has already been done, or a connected view of the experiments that have been made upon it. Such a history I shall here attempt, quoting every where the authors of such facts as are not taken from my own diaries, and, where any doubts arise on comparing the different accounts, making new trials.

SECT.

## S E C T. I.

*Of the general properties of platina considered by itself, or independent of its disposition to unite or not unite with other bodies.*

I. *Description of Platina.*

**P**LATINA in grains, as brought into England, is of a shining whitish colour, somewhat approaching to that of silver, but less white: from this resemblance, which becomes much greater when the platina has passed through certain operations, it probably, as already taken notice, received its name. Mr. Macquer resembles its colour to that of coarse iron filings unruined, but all I have seen was a good deal whiter than any iron filings: this difference from iron is mentioned also expressly by Mr. Scheffer, for while he had no suspicion of the platina being a new distinct metal, he says it seemed to be iron which by some accident had been made externally white. Mr. Marggraf calls the colour white inclining a little to that of lead.

The colour of platina is not tarnished or altered, so far as I have observed, by air or moisture, or by any exhalations that are commonly diffused through the atmosphere: it resists vapours which discolour silver, and appears equally permanent with that of pure gold.

The grains are of various sizes: some few are as large as linseed, but most of them a good deal smaller. Their figure also is various and irregular: some approach to a triangular, others rather to a circular form: most of them are flat, none globular, and few of any great convexity: the surface is smooth, with the edges and angles generally rounded off. On viewing them with a microscope, the  
surface.

surface appeared in some parts uneven: the prominencies looked bright and polished; the cavities dark coloured and roughish, as if they were sprinkled with a powdery matter. A few of the grains were attracted, though very weakly, by a magnetic bar.

## II. *Substances mixed with the native platina.*

WITH the grains of platina, above described, several heterogeneous matters are intermingled; some of which are in small particles or dust, separable by a fine sieve; others larger, so as to be distinguished by the eye and picked out. These substances, in the different parcels of platina which I examined, were the following.

1. A considerable quantity of blackish dust, which appeared to consist of two dissimilar substances; a part of it being attracted vigorously by a magnetic bar, and a part not attracted at all. The part attracted is of a deep sparkling black colour, much resembling the black sand from Virginia: the rest is of a brownish hue, and has several bright particles intermixed, which appear to be fragments of the grains of platina itself. It is probable that the roughness and dark colour of the cavities of the grains of platina, and the magnetic quality of some of the grains, proceed from some portion of these extraneous powders adhering in them.

2. Among the larger grains of platina, separated by means of a coarse sieve, were observed sundry irregular dark-coloured particles, some blackish, others with a cast of brownish-red, in appearance resembling fragments of emery or loadstone. Some of these were attracted by the magnet, very weakly, and others not at all. The unmagnetic dust of the preceding paragraph seems to be only smaller fragments of this last kind of matter.

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3. There were some rough yellow particles, very malleable, which appeared to be gold, though not free from a mixture of platina. A further examination of these golden particles will be given hereafter. Their quantity differs in different parcels of the mineral: twelve ounces of the richest that has come to my hands being diligently picked, with the assistance of a magnifying glass, the grains partly or entirely yellow amounted to about two pennyweights, or one part on a hundred and twenty of the mixt.

4. A few globules of quicksilver containing gold, with some particles of platina intermixed and pretty strongly adhering. Mr. Marggraf likewise observed some quicksilver among the platina which he examined, having been induced to look for it with attention, by finding, that when an ounce of platina had been urged with a strong fire in a glass retort, a little true running mercury came over into the receiver. The yielding of quicksilver and containing some magnetic parts, the former of which is particularly mentioned in the first of my papers in the Philosophical Transactions, and the latter not only there, but by all those I know of who have given any experimental account of platina, are ranked by Vogel among the new properties of this mineral discovered by Marggraf.

5. Some fine colourless transparent particles, which were hard to break under the hammer, and were not sensibly acted upon by aquafortis. These are probably fragments of the hard kind of stone, which frequently invests ores in mines, and in which native gold is ofteneft found lodged, called by the Germans *quartz*, but which has not, that I know of, received any distinctive English name.

6. A very few irregular particles of a jet black colour. These broke very easily, and looked like the finer sorts of

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pitcoal : laid on a red hot iron, they emitted a yellowish smoke, and smelt like burning coal.

The foregoing observations afford some room to suspect, that this mineral has not come to us in its native form, but has probably been ground in mills, and worked with quick-silver, in order to extract the particles of gold intermixed with it. But its mineral history will be considered more particularly after we have gone through the history of the experiments, as some points cannot till then be sufficiently understood. It is here only to be well attended to, that all these matters are entirely adventitious to the platina; that their quantities are very variable, and that one or more of them, in some parcels, seem to be altogether wanting, the magnetic or ferruginous matter being always the most considerable, and possibly the only constant admixture.

### III. *Specific Gravity of Platina.*

THE mineral called platina being, as we have before seen, a mixture of very dissimilar matters not uniformly blended, I weighed hydrostatically several different parcels, taking sometimes four or five ounces for one experiment, and in one twelve ounces. In most of the trials, the gravity turned out, to that of water, very nearly as 17 to 1: it was never less than 16,500, nor greater than 17,200. The gravity of platina was examined also by Dr. Pemberton and Mr. Ellicott, who both reported it to be about 17. The late Mr. Sparkes informed me, that a specimen which he made trial of turned out but 16; and Dr. Davies, that he weighed a parcel whose gravity was found to be 17,233.

To come as near as might be to the specific weight of the pure platina, I separated a quantity of the larger grains by a coarse sieve, and endeavoured to cleanse them from the dust that might adhere, by boiling them in aquafortis, mixing them with sal ammoniac and forcing off the salt  
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by fire, and afterwards washing them with water. The gravity of these was found on many trials to be upwards of 18, though the microscope still discovered a portion of blackish matter in their cavities. Fahrenheits thermometer standing at the fortieth degree, a quantity of these grains which weighed 642 in air, weighed in distilled water  $606\frac{1}{4}$ , whence the specific gravity comes out 18,213. It was doubtless the larger and purer grains that Mr. Marggraf examined, when he makes the gravity of platina to that of gold as  $18\frac{1}{2}$  to 19.

The remarkable weight of platina appears to have been the principal inducement for believing that it is rich in gold, and is still insisted on by many as a proof of its being so, agreeably to the general axiom already taken notice of in the history of gold, which, having long been universally received, men cannot easily think to be erroneous, that as mercury, among the bodies hitherto known, is the next in weight to gold, all bodies heavier than mercury, whose gravity is about 14, must therefore necessarily partake of gold. Accordingly it has been affirmed that a twentieth, a tenth, and some have gone so far as to pretend that a fourth part of platina is true gold, the rest being a ferruginous matter enveloping the gold.

But if we suppose platina to contain even this last quantity of gold, I apprehend that the same difficulty will still remain, and that the axiom will be as effectually overturned as if we suppose it to contain none. If the matter mixed with the gold in platina is ferruginous, its specific gravity cannot be admitted to be more than 8, for pure iron itself does not come up to that weight. Now if 8 parts of this matter lose 1 in water, 3,0000 parts will lose ,3750; and 1,0000 parts of gold, the gravity of this metal being about 19,300, will lose ,0518; so that 4,0000 parts of the compound will lose ,4268; whence, dividing 4,0000

by ,4268, we have 9,372 for the gravity of the compound: The gravity of platina should be no more than this, if its composition was such as is supposed; so that one part of gold, wrapt up in three of ferrugineous matter, is very far from accounting for the great weight of the mineral. To make the gravity 17, the quantity of gold ought to be 10 parts in 11 of the mass.

If it be supposed that the matter mixed with the gold is not iron, but something of a heavier kind, let us investigate what its weight must be. If gold be blended with three times its weight of another matter, and the gravity of the mixt be 17; then  $4\frac{1}{4}$  parts of gold, and  $12\frac{1}{4}$  of the other matter, will together lose 1 in water: the  $4\frac{1}{4}$  or 4,25 of gold lose ,22 in water, so that the  $12,75$  of the other matter must lose ,78, whence the gravity of this last comes out above 16. If platina therefore be supposed to contain gold because it approaches to gold in specific weight, we must still admit that there is a substance which does the same though it contains no gold.

To this way of reasoning the degraded gold of Mr. Boyle has been objected; which however does not seem to me at all to affect the argument. For in Boyles process, of which an account has been already given in the history of gold, page 206 of this volume, the gravity of the gold, by the mixture of an inconsiderable quantity of foreign matter, was diminished between a fifth and a sixth part, probably from accidental cavities in the mass; whereas here, according to the supposition we have been speaking of, the gravity of the compound, instead of being diminished, is increased almost to double of what it ought to be. There may indeed be some variation of gravity from the mixture of two bodies with one another, but of such an increase as this I believe it will not be pretended that there is any instance. The great weight of platina therefore, instead  
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of being a proof of its containing gold, affords rather a presumption of its being a ponderous body distinct from gold.

#### IV. *Malleability of Platina.*

SOME of the purer grains of platina, by gentle strokes of a flat hammer upon a smooth anvil, bore to be extended into thin plates, without breaking or cracking about the edges: some cracked before they had been much flattened, and discovered internally a close granulated texture: others were so brittle as to be reduced, without much difficulty, into powder. Even the tougher ones soon broke from rude blows in an iron mortar; and they seemed all to be more brittle when red hot than when cold.

Mr. Scheffer, in his little quantity of platina, did not take notice that the grains differed in toughness: the particles he tried having been of the more malleable kind, he makes platina in general to be as malleable a metal as the best iron. Mr. Macquer seems also to have tried only a single grain: he says he took one of the largest of the grains, and having beaten it with moderate strokes on a steel anvil, he found that it suffered itself to be flattened into a pretty thin plate, which however cracked upon continuing the beating. But Mr. Marggraf examined several grains, and observed the same difference in their malleability as I had done: some stretched considerably; others but a little, breaking from a few blows; whilst others bore to be extended into pretty thin plates: he takes notice that these last were mostly the convex grains.

Upon the whole, as many of the grains are apparently of considerable malleability, and as the brittleness of the others proceeds doubtless from some accidental cause, we can by no means refuse platina the title of a malleable metal; though little advantage can result from this property, unless means should be found of uniting the grains into larger masses.

V. *Platina*

*V. Platina exposed to the fire in vessels.*

1. AN ounce of platina, containing its usual admixture of magnetic dust, was kept for some time of a moderate red heat in an iron ladle. The white grains became dark coloured, and almost lost their metallic brightness; and the magnet seemed no longer to attract any part of the mixt: in other respects no alteration was observed.

2. Several ounces of platina, freed from the black dust, and in which no yellow particles could be seen, were heated to a strong red heat, and quenched in urine. The platina, as before, lost its brightness: many of the grains looked blackish, others of a rusty or reddish brown, and some of a high yellow colour; which last proved more malleable than platina, and appeared to be in great part gold. Surprised at this event, and imagining at first, agreeably to the common opinion, that the platina had suffered a decomposition, or been divested of its coat, I repeated the ignition and extinction upwards of thirty times, quenching the matter sometimes in urine, and sometimes in solution of sal ammoniac and other saline liquors: the platina continued still of the dark colour which it had contracted at first, and no more golden grains could be perceived. On examining the remainder of the packet of platina, the gold, which the first ignition had exhibited, was easily accounted for: the particles of gold, naturally intermingled among the platina, were covered with quicksilver, which had doubtless been added with a view to extract them; and the quicksilver, evaporating in the fire, had left the gold of its proper aspect. It is possible that others may have been imposed upon by the like appearances, and thought they had produced gold from the substance of the platina itself, when they had only collected the golden grains, which ought to be looked upon as entirely adventitious.

3. The

3. The platina, discoloured by the two foregoing experiments, was put into a crucible, which was covered, and kept for half an hour in a pretty strong fire, sufficient for the melting of cast iron. The platina lost the ill colour which it had contracted in a weaker heat, and became brighter and whiter than it had been at first. The grains stuck together, so as to come out of the crucible in one lump; but they readily fell asunder again on a slight blow, and did not appear to have at all melted, or altered their shape.

4. Some of this brightened platina, kept in a moderate red heat for an hour, contracted a dark colour as before; and being afterwards urged hastily with a strong fire, it became again bright, almost like silver. I tried the malleability of several of the grains, both when discoloured and when brightened by fire, and found that in both states, as in the crude mineral, some bore to be considerably extended, while others cracked or broke from a blow or two of the hammer.

5. I proceeded to try the effect of greater degrees of heat, having fitted up for this purpose a blast-furnace or forge with two pair of large bellows. An ounce of platina, in a black-lead crucible, was urged in this furnace with a sea-coal fire, for more than an hour. The heat was so vehement, that the crucible in great part vitrefied; and the slip of Windfor brick which it was covered with, though defended by a thin coating of Sturbridge clay, as also the internal parts of the furnace opposite to the bellowses, melted and run down. The grains of platina remained unmelted, being only superficially united into a lump of the figure of the bottom of the crucible: their colour was a good deal brighter and more silvery than at first; and they seemed to cohere more firmly than those which had undergone the weaker heat in No. 3.

6. The.

6. The foregoing experiment was many times repeated; in different kinds of crucibles, both German and English; with fires of charcoal, of common sea-coal, and of sea-coal coated or charred. In the most intense fires I was able to excite, such as neither the best of the crucibles, nor the furnace, could long support, the platina did not appear to melt, or soften, or alter its figure. I sometimes indeed obtained a few globular drops, of the size of small shot, of smooth surfaces, which broke easily on the anvil, and looked internally grey: these drops had evidently been melted, but it is probable that they were not pure platina, and that the fusion was owing to an admixture of the ferruginous part of the mineral, or of the golden grains: for when the purer picked grains of platina were employed, there was never any appearance of melted particles; and those parcels of the mineral which had once yielded some melted drops, could never be made to afford more, though urged with fires at least as vehement as the first time. The cohesion of the grains of platina seemed to begin in a moderately strong red heat, and to become firmer and firmer as the fire was made more violent, though I never found them cohere so much as to resist a small blow of a hammer. The colour, after strong fire, was almost always bright and white, except on the surface of the mass, which was often changed to a dark brownish, with sometimes a faint yellowish tinge: in one experiment, the metal, when violently heated, having been quenched in cold water, the grains which composed the internal part of the lump acquired a violet or purple colour.

7. I picked out some of the larger and brighter particles of platina, to the weight of about fifty grains, and spread them on the bottom of a smooth crucible: the vessel being covered, and kept in a vehement fire, as in the above experiments, for about an hour, the platina cohered but slightly,

flightly, and being laid again in the balance, it rather outweighed its former counterpoise which had been left in the scale. From this experiment, which was two or three times repeated with the same event, I concluded, in the first paper, published in the Philosophical Transactions, that platina does not lose of its weight in the fire: Mr. Marggraf and Mr. Macquer have since found, that it not only does not lose, but really gains weight, and that when the fire is long continued, the gain is very considerable.

8. Mr. Marggraf put two ounces of crude platina in a scorifying dish under a muffle, and kept up a strong fire for two hours, stirring the platina at times with an iron rod. He observed that no fumes arose; that when grown cold, the metal looked like shavings of lead run together, but blacker and without metallic lustre; and that its weight was not diminished but increased, for it weighed two ounces and ten grains, or one part in ninety-six more than it did at first.

9. He repeated the experiment with one ounce of platina, in a covered crucible, placed on a proper support, in a melting furnace, which, by means of a long pipe for conveying in the air under the ash pit, and a long narrow chimney on the top, gives the strongest fire of all the furnaces in his laboratory. The fire being kept up in its greatest vehemence between three and four hours, the platina was found sticking together but not melted, and weighed five or nearer six grains, that is near one part in eighty, more than at first. He takes notice that the grains were pretty easily separated by a blow of a hammer; that those in the internal part of the lump were whiter than at first, but that they were still in their original form; and that some of them bore to be flattened on the anvil.

10. Mr. Macquer put an ounce of platina into a German crucible, and exposed it to a strong fire for fifty hours, in a furnace whose heat, when continued for such a time, was capable of melting the mixtures which Mr. Pott says, in his *litbogeognofia*, yielded him glasses the most hard and the least fusible. On examining the platina after this trial, he found that it had not melted, and that the grains only stuck together so as to form one mass, which had exactly the figure of the bottom of the crucible, and which had shrunk from the vessel so as to come freely out; that all the surface of the mass was tarnished and blackened, and changed to a slate colour, with a diminution of the metallic brilliancy; that the internal part of the crucible, where the platina had touched it, was tinged as if filings of iron had been calcined in it; and that on weighing the platina after the operation, it was found increased fourteen grains, which amount (the French ounce consisting of five hundred and seventy-six grains) to about one part in forty-one. The same platina, submitted to another operation similar to the foregoing, received a further increase of two grains, the augmentation in all being sixteen grains, or one part in thirty-six. There could be no suspicion, he says, of any coals or ashes falling in, because the crucible was in a part of the furnace where such matters could have no access, and because it was also closely covered, though not luted. As the increase was inconsiderable in the second operation, he judges there would have been little or none on a third repetition. We may add, that since after fifty hours strong fire, a further continuance of heat occasioned still a very sensible augmentation of weight, the difference between the result of this experiment and Mr. Marggrafs, in regard to the quantity of the augmentation, may be easily accounted for, from the different lengths of time that the fires were continued.

11. It is well known to the chemists, that the metals called imperfect, or those which calcine in the fire, gain weight in their calcination; a phenomenon not a little astonishing, and of which they have not been able to assign any probable cause, unless it be the absorption of air. As platina appears plainly, from many of its properties, not to be one of the imperfect metals, Mr. Macquer very justly suspects, that the increase of weight in the above experiments was owing to the calcination of some heterogeneous substances mixed with the platina. The ferruginous lining which it left in the crucible, and the obscuration of the colour, seemed to confirm this conjecture, and he further took notice, that after the second calcination there were some grains of a friable matter like scales of iron, and that the magnetic sand was no longer black and brilliant, but of the same slate grey colour with the platina. It may here be observed, that if there was no mistake in Mr. Macquers weights, the quantity of this heterogeneous calcinable matter must be very considerable. Of all the experiments I can recollect of the calcination of bodies, there is no one in which the increase was so great as that which Mr. Scheffer allows to iron, viz. one third of its weight, as we shall see hereafter in the sixth section of this history: admitting even this augmentation to the calcinable matter in platina, the quantity of this matter, to produce an augmentation of sixteen grains on the ounce, must be forty-eight grains, or one eleventh part of the platina.

12. The observations in the foregoing paragraph account for the difference between my experiments No. 7, and those of M. Marggraf and Macquer in No, 8, 9, and 10; mine having been made with the purer grains, and theirs with the entire mineral containing its common mixture of calcinable parts. For further satisfaction in this point, I

took 360 grains of the larger and brighter particles picked out from platina, and the same quantity of the blackish dust separated from it by a sieve: the two parcels, in two smooth scorifying dishes, were kept under a muffle, in a very strong heat, for five hours; and that both of them might undergo an heat as equal as possible, the places of the two dishes were interchanged about the middle of the process. When cold, the picked platina, weighed with great exactness, was found to have gained two grains, or one part in a hundred and eighty; while the dust was increased near nine grains, or one part in forty. It was observed that the picked platina had become darker coloured than it was at first, but the dust paler; and that the picked platina cohered very slightly, but the dust was agglutinated into a firm cake not easily to be broken between the fingers. It must be observed that what is here called dust contains a considerable proportion of true platina, divided into particles as fine as those of the impure matter; and consequently that the quantity of impure matter in the picked platina cannot be judged of from the proportional augmentations which the two parcels received in the fire. But we shall here drop an enquiry, which does not seem important enough to deserve the trouble of any further prosecution, especially as we shall hereafter find means of attacking these calcinable parts more effectually than by simple heat.

13. The experiments I had made (No. 5 and 6 of this article) seem to prove, that platina cannot be brought into fusion in the common crucibles, by any heat that the vessels themselves can support. Mr. Scheffer concludes also from his trials, that to melt it in a crucible is impossible, since it resists even a stronger fire, than that which vitrifies the best crucibles made of Waldenburg earth and quartz, which we may suppose, from this manner of speaking



ing of them, to be of a very good kind. Nevertheless, as the melting of platina, if it could be effected, would be a most important acquisition in regard to its chemical history and mechanic uses, Mr. Macquer made some further trials with this view. He exposed platina to the fire of a glasshouse furnace for five days and five nights, but without perceiving any other alterations than those already mentioned: and indeed the glasshouse fire could not be expected to subdue this refractory metal, which had already resisted fires much greater than the glasshouse furnace can produce, and greater than its materials or vessels can support.

14. For the last effort, Mr. Macquer had recourse to a forge, increasing the activity of the fire by an expedient similar to that which we have formerly mentioned in page 26 of the present work. The blast from the bellows was divided into two pipes, which entered the furnace at two opposite sides; and two other great bellowses were so disposed, that their blasts entered oppositely at the other two sides. Four ounces of platina, in a Hessian crucible, being placed in the middle of the furnace, the fire was excited by the bellowses to such a degree, that in less than an hour and a quarter, all the internal part of the furnace melted and run towards the bottom, forming in the lower part masses of glass, which, stopping up the orifices of the blast-pipes, made it necessary to discontinue the experiment: the crucible, which was all vitrified, being taken out some time after, appeared still of so dazzling a whiteness that the eye could not support its lustre: yet notwithstanding this extreme fire which the platina had suffered, it was no more melted than in the foregoing experiments; except that in the vitrifications, which surrounded the crucible, there were found some grains, of a silver whiteness, perfectly round, which appeared to have had.

had a very good fusion, but which, from a small blow of a hammer upon a steel anvil, fell into powder. Mr. Macquer appears therefore, in this utmost effort, to have produced no other effects than those which I had obtained; and his trials concur with the others in proving, that the best of the common furnaces, and melting vessels, will themselves melt sooner than the platina included in them.

VI. *Platina exposed to the fire in contact with the burning fuel.*

As the power of fire, upon metallic as well as earthy bodies, is remarkably promoted by the immediate contact of the burning fuel, and the impulse of air upon the subject, platina was exposed to its action in those circumstances. Mr. Scheffer seems to regret that he had not some pounds of the metal for a trial of this kind, but the process may be managed in such a manner, that a very little quantity can be made to suffice.

A crucible, having a bed of charcoal in it, was laid on its side among the fuel, in a good blast-furnace, with its mouth towards the nose of the bellows; and on the charcoal were spread four ounces of platina. The fire was vehemently urged for above an hour; during which an intense white flame passed through the crucible, and issued at an aperture made for that purpose in the end. Great part of the crucible was vitrified; but the grains of platina only superficially cohered and became brighter, without seeming to have at all softened or altered their shape.

The experiment was several times repeated and varied: common salt, whose fumes promote the vitrification of the crucibles themselves, was thrown on the fuel before the mouth of the vessel, and its fumes strongly impelled upon the platina: the lumps of platina which had undergone the preceding operations, were dropt, before the nose of the bellows, into violently-excited charcoal and sea-coal fires,

fires, so strong as almost instantly to melt off a piece of the end of the forged iron rod with which the fuel was at times stirred down. The platina still came out unmelted, and unaltered in its form; except that there were sometimes a few globular drops like those mentioned in the preceding article.

VII. *Platina exposed to a burning glass.*

AFTER all these fruitless attempts for the melting of platina, no other resource remains, for determining its fusibility or non-fusibility, than the action of large burning glasses or concaves; a trial which I have often regretted that I could not in this country find means of exposing it to. What has earnestly been wished for by all those, whom profit, curiosity, or science, have interested in these kinds of pursuits, Mr. Macquer and Mr. Baumé have endeavoured to supply.

They used a concave of plate glass, well silvered, twenty two inches in diameter, and of twenty-eight inches focus. Before they proceeded to try its effects on platina, they exposed to its action several other bodies, that some judgement might be formed of its force.

Black flint, powdered to prevent its crackling and flying about, and secured in a large piece of charcoal, bubbled up, and run into a transparent glass in less than half a minute. Hessian crucibles, and glasshouse pots, vitrified completely in three or four seconds. Forged iron smoked, melted, boiled, and changed into a vitrescent scoria, as soon as it was exposed to the focus. The gypsum of Montmartre, when the flat sides of the plates or leaves, of which it is composed, were presented to the glass, did not shew the least disposition to melt; but on presenting a transverse section of it, or the edges of the plates, it melted in an instant, with a hissing noise, into a brownish-yellow matter..

matter. Calcareous stones did not completely melt; but there was detached from them a circle, more compact than the rest of the mass, and of the size of the focus; the separation of which seemed to be occasioned by the shrinking of the matter which had begun to enter into fusion. The white calx of antimony, commonly called diaphoretic antimony, melted better than the calcareous stones, and changed into an opaque, pretty glossy substance, like white enamel.

They observe that the whiteness of the calcareous stones and the antimonial calx are of great disadvantage to their fusion, by reflecting great part of the sun's rays, so that the subject cannot undergo the full activity of the heat thrown upon it by the burning-glass: that the case is the same with metallic bodies, which melt so much the more difficultly in the focus, as they are the more white and polished: that this difference is so remarkable, that in the focus of the concave whose effects we have been speaking of, so fusible a metal as silver, when its surface was polished, did not melt at all: and that the whiteness of platina would doubtless in like manner have greatly weakened the action of the concave on it. Mess. Macquer and Baumé therefore took the platina which they had before kept five days in a glasshouse furnace, and which, while it had concreted into a lump large enough to be held in the focus, had at the same time become tarnished and browned on the surface, so as to be in a state the most favourable for the experiment. Their account of the experiment itself is as follows.

“ When the platina begun to feel the activity of the focus, it looked of a dazzling whiteness: from time to time there issued from it fiery sparks, and there arose a fume, very sensible, and even pretty considerable: in fine it entered into a true and good fusion, but it was not till the

the end of a minute and a half that this fusion took place. We melted it in this manner in five or six parts: none of the melted parts however run to the ground, all of them remaining fixed to the piece of platina, probably because they set and hardened as soon as they were no longer in the center of the focus. These melted parts were distinguished from the rest, by a silver brilliancy, and a rounded surface, shining and polished. We struck the largest of these melted masses upon a steel anvil, to examine its ductility: it flattened easily, and was reduced into a very thin plate, without breaking or cracking in the least; inso-much, that it appeared to us infinitely more malleable than the grains of platina are in their natural state, and that we believed it might be extended into as thin plates as gold and silver. This platina grew hard and rigid under the strokes of the hammer, as gold, silver, and other metals do: this rigidity was easily destroyed by the method practised for gold and silver, that is, by heating it to a white heat and letting it cool." Mr. Baumé, in his *manuel de chymie*, printed in 1763, takes notice of another property of the platina thus melted; that it is found to be of a specific weight approaching (*semblable*) to that of gold: on this, however, we can lay but little stress, as he had said before, in speaking of the crude grains of platina, that their specific weight is equal (*égale*) to that of gold.

The above experiment, though not a little curious and interesting, is by no means entirely satisfactory; and it were to be wished that some further trials were made, with burning-glasses of greater force, for ascertaining with more precision the real fusion of the platina, and for obtaining some quantity of the melted metal, that its ductility, gravity, hardness, and other properties, may be more satisfactorily examined. Thus much seems clear

from the experiment, that platina is a great deal more difficult of fusion than flint, and flint a great deal more so than gypsum; and as no means have been found of pushing common fire to such a height, as to produce either in flint or gypsum the least appearance of fusion, without the concurrence of the saline or earthy parts of the fuel, which serve as a flux for those bodies, though not for platina; there appears no room to hope, as the author seems to do towards the end of his memoir, that we shall ever be able to melt platina in great furnaces. It follows also, that the melted drops, which both Mr. Macquer and I obtained in our furnaces, could not be pure platina: for though it is not to be thought that our fires were of equal intensity with that to which the platina was here exposed, our drops had suffered a more perfect fusion, than those parts appear to have done that were melted in the focus of the burning-glass: the drops likewise had nothing of the malleability, which platina melted by the burning-glass is said to possess in so remarkable a degree, but on the contrary fell in powder under the hammer. If the fusion in one case was brought about by the mixture of some foreign metallic matter with the platina, we cannot be certain but in the other also the same cause may have concurred in a less degree; and consequently it is possible that pure platina may require for its fusion a heat still more vehement.

From the experiments related in this section I think it may be concluded, that platina is a silver-coloured metal, of considerable ductility, not fusible by the strongest fires, that can be excited in the furnaces, or sustained by the vessels, of the chemist or the workman; that it approaches to gold in one of the reputedly most discriminating characters of that metal, specific weight; and that it agrees with gold and silver in being fixt and uncalcinable by fire.

S E C T.

## S E C T. II.

*Of the action of Acids on Platina.*I. *Platina with the Vitriolic acid.*

SEVERAL parcels of the purer grains of platina were digested for some hours in a gentle heat, with the concentrated spirit called oil of vitriol, and with the same spirit diluted with different proportions of water. No solution happened, nor any alteration either in the liquors or the metal.

2. Three ounces of strong oil of vitriol were boiled with one ounce of platina, in a tall narrow-necked glass, for some hours. The liquor remained nearly of the same quantity as at first, and no change could be perceived either in it or in the platina.

3. The glass being cut off a little above the surface of the liquid, the fire was gradually increased, till the liquor, which now begun to evaporate freely, had, in five or six hours, wholly exhales, and left the platina dry and red hot. The metal, when grown cold, being washed with water and afterwards dried, its weight was found to be the same as at first, and the surface of the grains shewed no mark of corrosion. The only alteration observed was, that many of the grains had become dull coloured and brownish; an effect which, as we have already seen, simple heat produces, and which therefore must not be imputed to the action of the body superadded, when a heat sufficient to produce it is employed at the same time.

It appears therefore, that platina resists the pure vitriolic acid, which, by one or other of the above methods of application, dissolves or corrodes every other known metallic body except gold.

## II. *Platina with the Marine acid.*

1. WEAK and strong spirits of salt being digested separately with one third their weight of platina, in a gentle heat, for several hours, the liquors remained uncoloured, and the platina unaltered. The heat was afterwards increased, and the liquors kept strongly boiling till they had totally exhales, without making any sensible change in the platina.

2. When common salt is strongly heated, in mixture with certain vitriolic substances, its acid, forced out by the vitriolic acid, and resolved into fumes by the heat, corrodes some metallic bodies, on which, in its liquid state, it has no action. Two parts of decrepitated or dried sea salt were therefore mixed with three parts of green vitriol calcined to redness; three ounces of the mixture pressed smooth into a cementing pot; one ounce of platina spread evenly upon the surface, and some more of the mixture over it; the vessel closely covered and luted, and kept in a moderate red heat for twelve hours. On examining it when grown cold, the saline mixture was found to have melted, and formed a smooth uniform mass. The platina, which had sunk to the bottom, being separated from the mixture by washing, appeared to have suffered no change, though its weight was a little diminished.

3. The experiment was repeated with a less fusible mixture, called the regal cement, composed of one part of common salt, one of colcothar, or vitriol strongly calcined, and four of powdered red bricks. An ounce of platina, surrounded as above with six ounces of this composition, and cemented in a close vessel, with a red heat, for twenty hours, suffered no material change, though there was, as before, some deficiency in the weight. Many of the grains were discoloured; whereas, in the foregoing experiment



periment they were all nearly as bright and white as at first, on account, perhaps, of the mixture having melted, so as to wash and cleanse their surfaces.

4. Of the other metallic bodies, gold is the only one which resists the marine acid in the above way of application. As the platina in these experiments had no mark of dissolution, it was presumed that this metal likewise had resisted it; and that the deficiency in weight was owing to some of the smaller grains having been washed off along with the ponderous metallic matter of the vitriol. The experiment was therefore varied, by substituting, to the foregoing mixtures, mercury-sublimate, a combination of the concentrated marine acid with quicksilver: when this compound is mixed with any one of the common metals, gold excepted, and the mixture exposed to a proper heat, the quicksilver separates and exhales, while the acid unites with the metal. An ounce of platina was spread upon three ounces of powdered sublimate in a glass vessel, which being set in a moderate sand heat, the sublimate totally arose, leaving the platina of its original weight, and uncorroded, though discoloured a little.

5. As the action of sublimate on bodies depends not only on the acid being capable of corroding them, but on its having a stronger affinity to them than it has to the mercury, that is, a disposition to unite with them in preference to the mercury; it is possible that there may be bodies, really corrodible by the acid, but which, having less affinity to it than mercury has, will of consequence resist the action of sublimate. The regal cement was therefore again had recourse to, but that none of the grains of platina might be in danger of being lost, twice their weight of gold was melted with them, and the mixture carefully hammered into a thin plate. A piece of the plate, weighing fifty grains, was surrounded with  
regal.

regal cement, the crucible covered and luted, and kept for twenty hours in a red heat. On examining the metal, it was found to retain the whiteness and brittleness, which gold constantly receives from so large a proportion of platina, and to have lost in weight about half a grain, or one hundredth part. This loss proceeded perhaps from alloy in the gold employed, which was above standard, but not perfectly fine, or perhaps from the dissolution of some of the heterogeneous parts of the platina, but by no means from the platina itself; for the same plate, cemented again with fresh mixture for the same length of time, suffered no further diminution. If the marine acid was capable of corroding the platina, the corrosion would have continued in the second process, and instead of a hundredth part, near a third part would have been eaten out. This experiment therefore determines with certainty the resistance of platina to the marine fumes; and that the regal cement, so called from its being supposed to purify gold from all heterogeneous metallic bodies, is incapable of separating platina from it.

6. There are circumstances in which gold itself is dissolved by the pure marine acid; as when it has been melted with tin, and the mixture beaten into powder and calcined; or when it has been reduced into the form of a calx by precipitation from other menstrua. Platina calcined with tin, and some of the precipitates of platina of which an account will be given in the next section, were digested in spirit of salt, with a moderate heat, for several hours: the reddish yellow colour which the menstruum acquired, shewed that a part of the platina was dissolved, though it seemed to dissolve somewhat more difficultly, and more sparingly, than gold treated in the same manner.

### III. *Platina*

### III. *Platina with the Nitrous acid.*

1. SPIRIT of nitre diluted with water, proof aquafortis, and the strong smoking nitrous spirit, were digested separately with one third their weight of platina, in a gentle heat, for several hours. During the digestion, some small bubbles were observed, as if a dissolution was beginning, but the liquors acquired no colour, and the fire being increased, so as to keep them boiling till they had totally evaporated, the platina remained unchanged, except only that many of the grains had become discoloured.

2. Platina was treated likewise with nitrous cements, by processes similar to those in which it had been exposed to the marine fumes. An ounce of pure nitre, and an ounce and a half of green vitriol calcined to redness, were ground together, part of the mixture pressed smooth into a crucible, over which was spread an ounce of platina, and the rest of the mixture above it. The crucible was covered and luted, and the fire gradually raised, so as to make the vessel of a full red heat, in which state it was continued for seven or eight hours. Red nitrous fumes issued copiously through some small cracks which they had forced in the luting. The crucible being grown cold, the mixture was found not melted or baked together, but loose and powdery. The platina was of the same weight and appearance as at first, except that many of the grains had become, as in the foregoing experiments, dull coloured or brownish.

### IV. *Additional experiments with the foregoing acids, &c. on platina.*

Mr. MARGGRAF has given some experiments on this head, which having been conducted in a somewhat different manner from mine, he took notice of some phenomena

mena which did not occur to me. They were all performed in small glass retorts, with receivers adapted to them; and the fire gradually raised, so as to make the retorts red hot. In this manner he treated platina with eight times its weight of each of the three foregoing acids; with twice its weight of mercury-sublimate; with twice its weight of sal ammoniac; and with thrice its weight of the mixture called sal alembrot, composed of one part of mercury-sublimate and two of sal ammoniac. The quantity of platina in each experiment was sixty grains.

With the nitrous and marine acids, he had a white crystalline sublimate in the neck of the retort, which, viewed through a magnifying glass, looked like crystalline arsenic, but whose quantity was too small to be submitted to any further examination. When the marine acid was used, there was also another sublimate of a reddish colour; and in all cases, the remaining platina was changed in part to a reddish brown. Mercury-sublimate arose uncoloured, and left the platina of a dark greyish colour, here and there reddish. The sal alembrot arose also perfectly white, but was followed by a little yellowish matter: the remaining platina was of a bright whiteness, almost like silver. With sal ammoniac there was a fine yellow sublimate (erroneously called blue in the Berlin memoirs) like that which rises from a mixture of this salt with iron; the remaining platina was rather whiter than at first, and after some time grew a little moist in the air.

Mr. Marggraf expressly mentions his using in these experiments the crude unpicked mineral; whereas in mine only the larger white grains were employed, from which all the heterogeneous parts and ill coloured grains, that could be distinguished by a good magnifier, had been carefully picked out. It is pretty certain, that the sublimates did not proceed from the platina itself, but from its admixtures,

mixtures, the white one possibly from the mercurial globules united with the acids, and the yellow from the ferrugineous parts. The author himself concludes from the experiments, that the acids have no action on the true platina, but attack in some measure its ferrugineous matter; and that the marine acid seems to have this effect in a greater degree than the other two.

V. *Platina with aqua regia.*

1. AQUA REGIA, the proper menstruum of gold, being poured upon platina, begun to act upon it slightly in the cold, and by the assistance of heat slowly and difficultly dissolved it; acquiring at first a yellow colour, which deepened by degrees, as the menstruum became more saturated, into a dark, almost opaque, brownish red.

2. The experiment was several times repeated, with different sorts of aquæ regiæ, made by dissolving sea salt and sal ammoniac, separately, in four times their weight of aquafortis, and by abstracting the nitrous spirit in a retort from the same proportion of each of the salts. All these menstrua dissolved the platina; and it did not appear to me that one dissolved it more readily, or in greater quantity than another. Mr. Macquer tried also several aquæ regiæ, composed of different proportions of the nitrous and marine acids, and found that a mixture of equal parts of the two spirits was one of those which answered the best.

3. In order to determine the quantity of menstruum necessary for the dissolution, I prepared an aqua regia by diluting ten ounces and a half of strong smoking spirit of nitre with eight ounces of water, and abstracting the mixture from six ounces of common salt. Five ounces of this aqua regia, which may be reckoned to contain three ounces of very strong acid spirit, were poured upon one ounce of

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platina,

platina, in a retort, to which was adapted a recipient. A moderate heat being applied, the menstruum acted pretty briskly, and red fumes arose in abundance. When about two thirds of the liquor had come over, the action was scarcely or not at all sensible, though the fire was considerably raised. The distilled liquor, which appeared of a light reddish colour, being poured back again into the retort, the dissolution begun afresh: the vapour, which now came over, was much paler than the first. The cohobation being repeated four times, the distilled liquor proved paler and paler every time: at length both the fumes and action ceased, though the fire was augmented, and a considerable part of the platina remained undissolved. The solution was therefore poured off, some more of the menstruum added, the distillation and cohobation renewed, and these processes repeated, till all the platina appeared to be taken up, except a little blackish matter which seemed to be its impurities. The last portions of the menstruum seeming not to be sufficiently saturated, some more platina was added; and after the acid had ceased to act, the remaining platina was dried and weighed, to see how much of it had been dissolved. It was found, that by this way of application, one ounce of platina was dissolved by eight ounces and a quarter of the menstruum; which quantity of the menstruum, as appears from the manner of its preparation, consisted of about four ounces and a half of strong acid spirit, diluted with three ounces and three quarters of water; whereas, when the digestion was performed in open vessels, and the fumes suffered to escape, about fourteen ounces of the above menstruum, containing nearly eight ounces of strong acid spirit, were necessary for dissolving one ounce of platina. Platina appears to require a much greater quantity than gold, and to dissolve far more difficultly.

4. Marggraf used an aqua regia composed of one part of sal ammoniac and sixteen parts of aquafortis; and found that twenty-four ounces of this menstruum were necessary for one ounce of platina. It may be suspected that the quantity of sal ammoniac was not here sufficient for enabling all the aquafortis to act on the platina, so that the metal was dissolved only by a part of the menstruum, the rest being superfluous aquafortis. The author observes, that the solution deposited in the cold small reddish crystals: yet he distilled off one half of it in a retort, and does not take notice of any crystallization happening in the concentrated residuum; from whence it seems to follow, that one half of the liquor was inessential to the dissolution.

5. Macquer made an experiment of the same kind, which agrees nearer with mine: of his aqua regia, composed of equal parts of the nitrous and marine acids, sixteen ounces dissolved, by digestion, one ounce of platina; and in my trials, about fourteen ounces were found to suffice. Acid spirits differ so much in their strength, and the dissolution is so much influenced by the vapours being more or less confined during the process, as appears from the experiments above related, that an exact agreement in this point is not to be expected.

6. In all the dissolutions of platina, a portion of blackish matter remained at the bottom, whether the platina had or had not been separated from its black dust. In some experiments, where the purer grains of the metal were used, the quantity of this indissoluble matter amounted to about six grains on the ounce, or an eightieth part: where the mineral was taken entire, without any separation of its heterogeneous mixtures, the residuum was in one trial above a fortieth, and in another about a thirtieth part. The proportion could not be determined with much exactness, the indissoluble substance depending

from the action of the acid some minute particles of the metal itself.

7. Great part of this residuum, as Marggraf observes, is attracted by the magnet ; its ferruginous principle being probably bedded in sandy matter, so that the acid could not reach it. As the finest grains of the metal leave always more or less of an indissoluble substance, it follows that platina is made somewhat purer by the dissolution.

All the experiments related in this section concur in establishing a strong agreement between platina and gold. There are some other metals which dissolve indeed, and with much more facility, in aqua regia ; but to resist either the pure vitriolic acid, or the marine acid, or the nitrous acid, in the circumstances wherein gold and platina resist them, are properties peculiar to these two.

### S E C T. III.

#### *Experiments on Solution of Platina.*

##### *I. Colour of the Solution, and trials of it for staining.*

**S**OLUTIONS of platina in aqua regia, when saturated with the metal, are of a dark, almost opaque, brown-red colour ; when only slightly impregnated, yellow like those of gold. A few drops of the saturated liquor tinge a large quantity of water of a fine golden hue. I know of no other metallic body whose solutions in acids are so rich or diffusive in colour, or tinge such large quantities of watery fluids.

Notwithstanding this diffusiveness of colour of the liquor itself, and its resemblance when diluted to solutions of gold, it is little disposed to communicate any colour to other bodies, and in this respect it differs remarkably from  
gold.



gold. It corrodes the skin, making it harsh and rough, but I have not observed that it gives any stain, not even the yellow one which the menstruum by itself communicates to the skin. Ivory, feathers, silk, wood, and linen, were dipt in the diluted liquor and exposed to the sun, and the dipping and drying repeated three or four times: they all became brown, from the colouring matter of the solution having dried upon the surface; but water washed it off readily, and left them colourless as at first, except that the silk retained a slight brownishness after the washing. The solution dropt upon warm marble, immediately corroded it, but without giving any colour. Dropt into infusions of cochineal, it did not heighten but destroy the red or purplish colour, and changed them to a brownish or blackish: some of the mixtures applied on paper with a pencil, appeared nearly of the same hue with Indian ink in its paler shades.

## II. *Crystallization of Platina.*

SOLUTIONS of platina crystallize much more easily than those of gold. As a considerable heat is necessary for making the aqua regia saturate itself with the metal, the fatiated solution generally deposites, by the time it is grown cold, a brownish red sediment, which is no other than a number of minute crystals. A quantity of the solution having been set by in an open glass, in warm weather, the superfluous moisture gradually exhaling left moderately large crystals, of a dark almost opaque red colour, of irregular figures, variously joined together, most of them in form of leaves, like flowers of benzoin but thicker. Their taste was nauseous and somewhat sharp, but not near so corrosive as might be expected from the great quantity of nitrous and marine acids combined with the metal. Washed with proof spirit, they became somewhat paler, but still remained.

remained of a high colour, resembling that of the deeper chives of saffron. In a moderate heat, they seemed to melt, though only imperfectly, and emitted white fumes smelling of spirit of salt; at length they fell into a dusky ash coloured calx, staining the tobacco-pipe, in which they were exposed to the fire, of a pale dull reddish colour.

### III. *Volatilization of Platina.*

THIS metal, of itself as fixed in the fire as gold, appears to be equally volatilized by the hasty abstraction of an aqua regia made with sal ammoniac. Marggraf put into a glass retort six ounces of a solution of platina made in a mixture of sixteen parts of aquafortis and one part of sal ammoniac: having set the retort in sand, and fitted to it a receiver, he drew off the liquid by a gradual fire, which at last was increased, so as to make the retort red hot and ready to melt. There remained at the bottom a reddish-brown powder, which being further calcined under a muffle, became more of a brilliant blackish hue. In the neck of the retort was found a brown-red sublimate, which, on exposure for some days to the air, run into a red liquor resembling solution of platina. He poured some of this liquor on a polished copper plate, and found that the platina, after some time, precipitated upon the copper, as it does from its common solutions, covering the copper with a shining blackish powder.

### IV. *Solution of platina, with vitriolic acid.*

To a solution of platina, diluted with water, I added some strong spirit, called oil, of vitriol: no precipitation or change of colour ensued, though a large quantity of the acid was at different times dropt in, and the mixture suffered to stand for several days. But on adding the same strong vitriolic spirit to an undiluted solution of platina,  
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the liquor immediately became turbid, and a dusky coloured matter soon precipitated. The precipitate was not redissolved on the affusion of water; nor was the precipitation prevented by adding water immediately after the acid had been dropt in.

V. *Solution of platina, with volatile alcali.*

THE spirits of sal ammoniac, prepared both by quicklime and by fixt alkaline salts, added to solutions of platina diluted with water, precipitated a dark red sparkling powder: but in whatever quantity the spirits were added, the precipitation was not total, a considerable part of the platina remaining dissolved so as to communicate a high yellow colour to the liquor. The red precipitate, dried, and exposed to the fire in an iron ladle, became blackish, without discovering any thing of the fulminating power which precipitates of gold, prepared in the same manner, have in a remarkable degree. On washing some of the precipitate upon a filter, with repeated additions of water, greatest part of it dissolved, only a small quantity of blackish matter remaining on the paper, and the liquor passing through of a deep bright golden colour: a very large quantity of water was tinged of this colour by a small one of the powder.

VI. *Solution of platina, with vegetable fixt alcali.*

SALT of tartar, salt of wormwood, fixt nitre, and the *lixivium saponarium* of the London pharmacopœia, had the same effect on solution of platina as the volatile spirits in the foregoing article, except that the precipitates were of a much duller reddish colour, and less brilliant. The precipitation was equally imperfect; the liquor still continuing of a deep yellow colour, and greatest part of the precipitate being redissolved on the addition of water.

In the foregoing experiments, the precipitates of platina by volatile alcalies were of a dark kind of red colour and considerably sparkling, while those by the fixt were of a paler dull reddish with little brilliancy. In the accounts which others have given of these precipitations, this difference, in itself of small importance, is not taken notice of. Scheffer calls the precipitates by both alcalies simply red; and Marggraf calls them both orange yellow, a term applicable enough to the precipitates which I had obtained with the fixt alcalies, but not to those with the volatile. It should seem as if there had been some real differences in the appearances of our respective products, and I imagined that such differences might have arisen from differences in the solutions of platina made use of: some late trials appeared to countenance this suspicion, for while common solutions of platina yielded precipitates of the red kind, a solution of the crystals of platina made in water gave only yellow ones.

Macquer accounts for this difference of colour in another manner. He says the precipitate proves red only when the quantity of alkali is no more than just sufficient to satiate the acid; and that the more of the alkaline liquor we add beyond this point, the precipitate proves less and less red; agreeably to which his coadjutor Baumé says afterwards more determinately, in his *manuel de chymie*, that with a due quantity of fixt alkali the precipitate is orange yellow, and with an over quantity pale yellow. Mr. Macquer, judging from hence, that the redness was owing to a large quantity of acid retained by the platina, digested some of the red precipitate in a solution of fixt alkaline salt: the alkaline liquor, absorbing the acid, destroyed the red colour of the powder, and made it white. It has long been known, that precipitates carry down with them a portion both of the dissolvent and of the body they were precipitated

tated by: the author observes that this appears more sensible in our precipitate of platina, at least with regard to the dissolvent, than in most others; and that this observation discovers the cause of sundry singular phenomena, which I had remarked in the precipitation of platina, and of which I had not given the theory, as of the red precipitate being soluble in water, and of part of the platina remaining suspended whatever quantity of alcali we add in the cold: a detail and explication of these phenomena, with others of the same nature, he reserves for another memoir. Some experiments I have made do not very well agree with this theory, but I forbear any further observations till the authors memoir appears.

VII. *Solution of platina, with mineral fixt alcali.*

As the two foregoing kinds of alkaline salt precipitate platina only in part, there is a third which has not even that effect. The mineral alcali or basis of sea salt, the method of preparing which will be described in the following part of this history, produces no precipitation at all. This remarkable experiment, which we owe to Mr. Marggraf, will be further considered hereafter.

VIII. *Solution of platina, with Prussian alcali.*

Mr. MARGGRAF observes, that when solution of platina is mixed and saturated with a lixivium of fixt alcali that has been calcined with blood, it yields a fine blue precipitate, which in certain circumstances proves as beautiful as the best Prussian blue, though there falls also at the same time a little orange coloured matter. On repeating this experiment, the liquors when first mixed appeared of a pretty deep blue, but when the precipitate had settled, greatest part of it looked yellow, on account, probably, of the platina I made use of containing less fer-

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rugineous matter, or the alkaline lixivium being less saturated with the substance which tinges dissolved iron blue, than those which Mr. Marggraf employed.

To obtain a saturated solution of this tinging substance, which cannot be expected to be done by calcining alkaline salts with blood or other like matters, I digested some common Prussian blue both in solution of fixt alkaline salt, and in volatile spirit of sal ammoniac prepared with quicklime. Both menstrua soon became yellow; and the iron basis of the Prussian blue, thus freed from its colouring matter, remained in a rusty form. To both tinctures I added some more Prussian blue, till they ceased to have any action on it. The fixt alkali, along with the tinging substance, appeared to have taken up some of the iron; for it struck a blue colour with good aquafortis, with the acid of sulphur, and with distilled vinegar, in which there were no grounds to suspect any iron to be previously contained. The volatile tincture appeared free from iron, for in the same acid spirits it produced no change, though it instantly turned them blue when a little iron was first dissolved in them.

This saturated solution of the tinging substance was added by degrees to solution of platina. The liquor turned at first to a deep blue, but on further additions, to a greenish yellow. The precipitate was of two kinds, yellowish at the bottom, and blue on the top. The whole being shaken together and set by till next day, a white matter appeared at the bottom, above this a yellow, and on the top a more copious brownish grey. The liquor was of a deep gold colour.

#### IX. *Solution of platina, with compound salts.*

SOLUTIONS of alum, of sal mirabile, of vitriolated tartar, of the fusible salt of urine, made separately in water,  
and

and solution of chalk in aqua fortis, were found by Marggraf to produce no precipitation or apparent change in diluted solution of platina.

Sal ammoniac, one of the ingredients to which the menstruum owed its power of dissolving the platina at first, precipitated great part of it in form of a reddish or yellowish powder, nearly similar to that thrown down by alcalies. It is observable, that though neither sal ammoniac nor alcalies, separately, occasioned a complete precipitation, the liquor still remaining of a high colour; yet when one was added to the solution remaining after the action of the other, a new precipitate fell, which left the liquor colourless.

#### X. *Solution of platina, with vinous spirits.*

As gold is revived from its solutions by vinous spirits, and made to rise in yellow films to the surface; I mixed a solution of platina with a large proportion of highly rectified spirit of wine, and exposed the mixture for many days to the sun, in a wide-mouthed glass slightly covered with paper to keep out dust: there was no appearance of any yellow skin, nor was any other alteration perceived, than that the platina had begun to crystallize from the evaporation of the fluid.

Suspecting that though the liquor should really contain gold, yet the platina might strongly retain the gold and prevent its being separated by the spirit, I mixed three or four drops of solution of gold with two hundred drops of solution of platina, and after shaking them well together, added some rectified spirit of wine: the whole being exposed as above to the sun, a golden film was in a few days observed upon the surface.

XI. *Solution of platina, with essential oils.*

A COLOURLESS essential oil of rosemary was poured into about half its quantity of solution of platina, the mixture well shaken, and suffered to rest: the oil quickly arose to the surface without receiving any colour, and the acid underneath remained coloured as at first.

A composition of platina and gold, which had been melted together, being dissolved in aqua regia, and the solution treated in the same manner, the gold was imbibed by the oil, and the platina remained dissolved by the acid: the oil, loaded with the gold, appeared of a fine yellow colour, and on standing for a few hours threw off great part of the gold to the sides of the glass, in bright yellow films, which appeared to have no mixture of platina. Some other distilled oils were made trial of, with the same event.

XII. *Solution of platina, with æther.*

THE vitriolic æther or æthereal spirit of wine, the preparation of which has been described at the end of the eighth section of the history of gold, was poured into a solution of platina, and into a solution of a composition of platina and gold. The two vials being immediately stopp'd, to prevent the exhalation of the volatile fluid, and lightly shaken; the æther received no colour from the solution of platina, but became instantly yellow from that of the platina and gold.

XIII. *Solution of platina, with tin.*

As a minute proportion of gold contained in acid solutions is discoverable by their striking a purple colour with tin, some bright plates of pure tin were put into a solution of platina diluted with water. The plates in a  
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little time looked of a dark olive colour, and soon after were covered over with a reddish brown matter. The liquor became at first darker coloured, and afterwards, by degrees, as the precipitate fell, nearly colourless, without exhibiting the least appearance of a purplish or reddish hue.

Some platina was digested in a quantity of aqua regia sufficient to dissolve only about half of it, and the remainder was dissolved in a fresh portion of the menstruum. The two solutions, treated as above, yielded somewhat different phenomena, but no tendency to a purplish cast could be perceived in either. The latter solution, which looked yellow from its not being fully saturated with the platina, was, when diluted with water, almost colourless: nevertheless, on the addition of tin, it became yellow again, then of a dull red, and at last of a dark brownish red, considerably deeper than the other more saturated solution: on standing for some time it grew perfectly clear, depositing a paler yellowish precipitate.

To determine whether platina was capable of preventing a small proportion of gold from discovering itself in this way of trial, one drop of a solution of gold was let fall into some ounces of a diluted solution of platina. On adding some plates of tin, the liquor became quickly purple.

The foregoing experiments were made with a solution of the picked grains of platina. I submitted also to the four last trials, with tin, æther, essential oils, and vinous spirits, a solution made by digesting in aqua regia the entire mineral, with its mixture of yellow particles, as it comes to us; which solution, in all these trials, gave exactly the same appearances, as the other solution did after it had been first mixed with a very little quantity of solution of gold, striking a purple colour with tin, communicating a yellow tinge to æther and essential oils, and yielding a yellow film with rectified spirit of wine.

XIV. *Precipitate of platina exposed to a burning concave.*

Mr. MACQUER and Mr. Baumé, after examining the action of a burning concave on crude platina, as already mentioned in page 466, exposed the red precipitate of platina made by alcalies, to the focus of the same burning mirrour. “ It immediately begun to boil, and diminished considerably in volume : there arose at the same time a very abundant and very thick fume, smelling strongly of aqua regia, and which appeared so luminous and so white in the neighbourhood of the focus, that we could not decide whether it was not a true flame: the precipitate at the same time lost its red colour, to resume that which is natural to platina, and it now had the appearance of metalline lace. Being continued in the focus, the white fume smelling of aqua regia was succeeded by another fume or flame less copious, whose colour inclined to violet. A little time after, there was formed, in the hottest part of the focus, a button of smooth brilliant matter perfectly melted, and then the vapours ceased. Examining this button after it was grown cold, we found it to be a vitrescent opaque matter, of a hyacinth colour on the surface, internally blackish and pretty compact. We dare not affirm that this was a true vitrification of the platina in virtue of the saline matters which were joined to it in the precipitate: the experiment ought to be repeated with pure platina, and with a burning glass or concave stronger than that we used.” Indeed as the platina resumed its metallic aspect, it should seem to have been disengaged from the salts, before the time that the vitrification begun; and perhaps a button of blackish vitreous matter, formed in the middle of the focus, may be easily enough accounted for from the ferruginous calx, which the precipitate cannot be supposed to have been free from: see the experiments of the relation of platina

tina to vitreous bodies at the end of the following section. The matter on which the powdery precipitate was exposed to the focus of the burning concave, might also have contributed to the vitrification; what this matter was, the author does not mention.

The experiments of this section point out some striking differences between platina and gold; not only in the power of producing, when dissolved, a purple colour with tin, and communicating a like stain to different kinds of colourless subjects, a power for which gold is remarkable, and which platina wants; but likewise in properties more importantly characteristic, as they afford means of distinguishing and parting the two metals when blended together. They have shewn platina separated in part from its solutions, by a substance which does not at all separate gold, to wit, sal ammoniac; and gold separated completely by substances which do not at all separate platina, viz. the mineral alkali, vinous spirits, essential oils and æther. It appears likewise from these experiments, that besides the black dust which remains behind in the dissolution of platina, the part dissolved is not pure platina; for the blue colour produced by the Prussian alkali amounts to a proof that the solution contains iron.

#### S E C T. IV.

*Platina exposed to strong fires, with saline, inflammable, sulphureous, vitreous and earthy bodies.*

**H**AVING seen the effects of the purer acids on platina, and the general properties of its solutions, we shall proceed to apply to it what are commonly called *fluxes* and *dry menstrua*, that is, substances which either barely promote the fusion of metals without corroding them, or which corrode and unite with them, when properly

perly heated, nearly on the same principle as humid menstrua dissolve them.

### I. *Platina with Borax.*

HALF an ounce of platina was dropt into an ounce of melted borax, and urged with an intense fire for an hour. The platina appeared to have suffered no alteration, but the borax was changed to a dark blackish colour, probably from its having dissolved and vitrified some of the ferruginous dust. The whole was returned to the fire, which was kept up strong for a considerable time longer, till the borax had sunk through the crucible: it left the grains of platina of a bright white colour, slightly cohering but unaltered in form.

### II. *Platina with Alkali.*

I TREATED platina in the same manner both with the common fixt alkaline salts well purified, and with the caustic alkali prepared by evaporating soapboilers ley, but could not perceive that either of them had any other effect than contributing to brighten its colour. Mr. Marggraf mixed a dram of platina with half an ounce of salt of tartar, and gave them a vehement fire, in a close luted crucible, for two hours. When cold, he found a hard mixt, of a yellowish green colour, in which the platina was dispersed. The whole being separated, as much as possible, from pieces of the crucible, by scraping and washing, the water above the matter was next day found like gelly: the platina was whiter than usual, almost of the whiteness of silver, but of its wonted figure. The gelatinous consistence which the water acquired in this and some of the following experiments, is probably not owing to the platina, but to some of the earth of the crucible dissolved by the saline matter.

### III. *Platina*

III. *Platina with Nitre.*

NITRE, which reduces all the known metallic bodies, except gold, silver and quicksilver, into a calx, was mixed with equal its weight of platina, the mixture thrown into a red hot crucible, and the fire kept up for about a quarter of an hour. No deflagration happened; and the platina, freed from the salt by repeated washing with water, appeared to have suffered no other change than having its colour darkened, an effect which the simple heat would have produced in it. The nitre was nevertheless in great part alcalized.

Four ounces of platina and eight ounces of the purest nitre were put into a crucible, the crucible covered with a larger one inverted over it, and kept in strong cementation, in a wind furnace, for three days and three nights without intermission. The matter being now boiled in water to separate the salt, the platina looked rusty coloured, and had lost almost half its weight: the saline liquor, on being filtered, left a brownish powder somewhat more than equivalent to this diminution, and being afterwards evaporated to dryness, yielded a small quantity of a greenish caustic alkali. The same platina was cemented thrice more with the same quantities of fresh nitre, and the fire continued for three days and three nights every time. In the two first repetitions, a smaller quantity of a paler powder separated, and the remaining metal in good measure lost the rusty hue which it had contracted before. After the last cementation, the little quantity of metal which remained had much the same appearance as the platina at first: on washing it, there was scarcely any further separation of powdery matter, but the nitre was still alcalized. The platina was then mixed with sal ammoniac, and the salt sublimed in a Florence flask: the salt arose

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uncoloured, and left the metal white and bright. The powders separated in the cementation were treated in the same manner, and the sublimation repeated thirty times with fresh quantities of the salt: in the first sublimations, ferruginous yellow flowers arose, but at last the salt received no tinge, and the powder remained of a greyish colour.

Mr. Marggraf gives an account of an experiment of the same kind, in which he takes notice of some phenomena, which either did not occur, or were not attended to, in mine. He threw into a red hot crucible four ounces of nitre, and one ounce, or four hundred and eighty grains, of platina: no detonation happened, but a considerable fume arose. The fire being continued, with care to prevent the falling in of any piece of coal, the matter, after some time, begun to swell up, and a portion of it being taken out looked greenish: it afterwards turned to a deep olive green, and grew considerably tough and thick: after some hours of strong fire, it proved as thick as pap. The thick matter was taken out while hot with an iron spatula: it was of a deep olive-green colour. As much as possible of what adhered to the crucible was collected, and set to digest with the other in distilled water: next day the whole was as thick as gelly. Being then diluted with more water, stirred about, and suffered to settle, the liquid was poured off, and this repeated till all the lighter parts were washed over: this light matter, separated from the saline liquor by filtration, well washed on the filter with hot water, and dried, weighed two hundred and twenty-five grains: it was of a dark grey colour, and by strong calcination under a muffle became black like pitch. The more ponderous part was ground in a glass mortar, by which some more became fine enough to be washed over: this was of a clear brown colour, and amounted to thirty grains. The platina

tina weighed three hundred and ten grains, and consequently had lost above a third: it still resembled crude platina, and retained its lustre; the brownish rusty coat, with which mine appeared covered after the first cementations, having probably been here rubbed off in the grinding. The nitre was totally decomposed, and had acquired all the characters of alcalicity. The crucible and its support were tinged almost throughout of an amethyst colour, as usually happens in the calcination of manganese with nitre.

The platina was treated in the same manner with three ounces of fresh nitre. The crucible and its support were still tinged of a fine amethyst colour, the nitre was totally alcalized, and all other circumstances happened as in the first operation, except that the lighter parts, first washed off, weighed only sixty grains: by calcination they became, as before, of a pitchy blackness: the remaining powdery matter was of a clear grey, and weighed forty five grains: the platina, still bright, weighed two hundred and fifteen grains, or less than half of its first weight.

The operation was repeated with three ounces more of nitre. The crucible and its support were now less strongly tinged. The first washings gave two grains of a light powder, in appearance much resembling the Eckertberg blue earth; and by rubbing the rest of the platina in water, there were obtained forty grains of a light powder of a grey-brown colour. The platina lost in this operation but five grains; and so inconsiderable a diminution giving little hopes of any further effect from a repetition of the process, the experiment was here dropt.

It had been affirmed, that platina is a compound of gold and some other matter, so intimately combined together, as not to be separable without other methods of procedure than are commonly practised or known. An adept, in the pretended art of this higher metallurgic analysis,

boasted of having destroyed the heterogeneous matter, so as to leave the gold pure, by long continued and repeated cementations with nitre. To remove all scruples on this head, I permitted him to make the experiment of which I have above given a short account, and of which I have ventured to insert only such particulars as came under my own observation. The experiment, with which that of Mr. Marggraf, so far as it goes, sufficiently corresponds, was decisive. It shewed much the greatest part of the platina changed to a powder, and the remaining platina as remote from the nature of gold as it was at first. I tried it both by acids, and by cupellation with lead, a process of which an account will be given hereafter, and found it to preserve its own discriminating characters, without any marks of gold, though it appeared to be purer than platina in its common state. I tried also, by the same methods, the powders which had been separated in the cementations, after the reiterated sublimations of sal ammoniac from them; and found these likewise to be no other than platina, not reduced to a calx, but barely divided.

It may be presumed that the action of the nitre was not directly upon the platina itself, but on the iron matter, adhering to the surfaces of the grains, or more intimately blended in their substance; which iron particles being changed to a calx, the platina intermixed became divided along with them into a powdery state. This supposition accounts satisfactorily for the principal phenomena of the process; as the separation of the powder being plentiful in the first cementation, and more and more sparing in the following ones; the first powder being of a deep colour, and the others paler, as if the iron prevailed in the first, and the platina in the others; the powders yielding yellow ferruginous flowers with sal ammoniac, while the platina, that remained entire gave no colour to the salt.

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In regard to the pretensions to the obtaining of gold by this process, it is not perhaps unreasonable to suppose, that the remarkable separation of powdery matter in the cementation, and the appearance of some golden grains which had been naturally intermingled among those of the platina, led men of warm imaginations to anticipate the further effect of the process, and to make the assertion which the above experiments overturn.

#### IV. *Platina with common salt.*

AN ounce of common salt, dried, was kept in fusion with a dram of platina, in a close crucible, for an hour and a half. The salt appeared yellowish, and on breaking the mass, there were found in the middle of it some red crystalline grains. The platina was all at the bottom of the crucible, and preserved its figure, having suffered no change, except being made very white. The experiment was repeated with what is called regenerated common salt, and the phenomena were exactly the same. Both these experiments are from Marggraf.

#### V. *Platina with vitriolic salts.*

MARGGRAF mixed a dram of platina with some pure Glaubers *sal mirabile*, and kept the mixture in a strong fire for two hours: the salt sunk through the crucible, and left the platina of a dark grey colour: on washing the platina with water, and rubbing it in a glass mortar, there separated a little light matter of a bright blackish colour, and what remained was platina unchanged. A dram of platina, and an ounce of vitriolated tartar, were treated in the same manner: the salt melted and became reddish; the platina suffered no change, except that it looked somewhat more grey.

#### VI. *Platina*

VI. *Platina with the essential salts of urine.*

FROM putrefied urine inspissated to the consistence of a syrup, is obtained by crystallization a singular saline concrete, called the fusible or essential salt of urine, or microcosmic salt, containing the acid of phosphorus united with a volatile alkali. This salt, exposed to the fire, parts with its alkali, and assumes a glassy appearance; in which state, all the common metals, gold not excepted, are said to be corroded by it in fusion. A hundred and eighty grains of this salt were mixed with thirty grains of platina, and urged in a crucible with a strong fire for two hours: the platina was found unchanged at the bottom, covered with the salt, which likewise appeared little altered. Sixty grains of this salt, the same quantity of calcined borax, and thirty grains of platina, were treated in the same manner: there was a vitreous scoria, somewhat opaque, of a yellowish green colour: the salts and lighter parts being separated by washing, the dried platina appeared of its natural form, but whiter than at first.

After the crystallization of the foregoing salt from urine, there crystallizes another, not containing the phosphoric acid, and whose composition is as yet unknown. Three drams of this salt and half a dram of platina being urged with a strong fire in a close crucible, the salt run all through the crucible, and the platina, after rubbing in a mortar and washing with water, appeared in its original form, being only somewhat whiter than before. A dram of the salt, a dram of calcined borax, and a dram of platina, treated in the same manner, gave a green-yellowish, dark-chrysolite-coloured vitreous mass, under which lay the platina unaltered, except that as in the former case it was whiter than at first. All these experiments are from Marggraf.

VII. *Platina*

VII. *Platina with phosphoric acid.*

WHEN the phosphorus of urine is set on fire under a glass bell, nearly in the same manner in which sulphur has been usually burnt for obtaining its acid, it yields spongy flowers, in appearance much like those of zinc; and both the flowers, and what matter remains on the glass dish which the phosphorus was placed upon, imbibe moisture from the air and run into a thick acid liquor, which exposed to the fire leaves a dry matter that melts into a glassy form. Mr. Marggraf mixed sixty grains of platina with twice as much of this acid liquor, and put them into a retort, whose juncture with the receiver was only closed with paper. The watery moisture being drawn off by a gradual fire, the retort was set, while hot, upon burning coals, till it begun to melt; after which, being taken from the fire, a flash like lightening filled both the retort and receiver, and a violent explosion followed. The author very ingeniously, and with great probability, attributes this effect to a regenerated phosphorus, to which the iron mixed with the platina had contributed the inflammable principle; the action of which phosphorus could then only take place, when the abatement of the heat suffered air to pass in through the ill-closed juncture. The pieces of glass being collected, the bottom of the retort appeared covered with a white saline matter, which being scraped off, the platina was found under it unchanged. It is evident that the platina itself neither was, nor was supposed by the author to be, anywise concerned in producing the fulguration; though Vogel makes this fulguration one of the *new properties of platina* discovered by Marggraf.

VIII. *Platina*

VIII. *Platina with black flux, &c.*

THE black flux commonly employed by the chemists for the fusion of metallic minerals and calces, composed of one part of nitre and two of tartar mixed together and burnt in a covered vessel to an alkaline coal, was kept in fusion above an hour, in a close crucible, with one fourth its weight of platina. Compositions of wood-foot, charcoal powder, common salt, and wood ashes, directed by M. de Reaumur for changing forged iron into steel, were mixed with platina, and cemented several hours, in close crucibles, both with moderate degrees of heat, and with fires strongly excited. In all these trials I could not observe that the metal suffered any change, except that its colour was darkened.

IX. *Platina with sulphur.*

AN ounce of platina was spread upon twice its weight of sulphur, with which some powdered charcoal had been previously mixed, to prevent its becoming fluid in the fire, so as to suffer the platina to subside. The crucible, having another crucible, with a hole in the bottom, inverted into its mouth, was kept in a cementing furnace for some hours: being then taken out, it was found that the sulphur had entirely exhaled; and that the platina, separated by washing from the charcoal powder, had the same weight and appearance as at first, except that its colour was changed to a blackish: by rubbing it in a glass mortar with a little alkaline salt and water, the blackness was destroyed, and its original brightness restored. I varied the experiment, by strongly heating the platina in a crucible by itself, and repeatedly throwing upon it pieces of sulphur: it still remained unaltered, the sulphur seeming to have no more action on this metal than on gold.

X. *Platina*

X. *Platina with sulphurated alcali.*

As fixed alkaline salts enable sulphur to dissolve gold in fusion, I exposed platina to the fire with a mixture of equal parts of sulphur and fixt alcali, called *hepar sulphuris*, or liver of sulphur. After a considerable heat had been continued for some time, and the matter now and then stirred with a clean tobacco pipe, the crucible was taken out, and the mixture digested in water. Among the matter that remained undissolved, only a few particles of platina could be distinguished; and the examination having been carried no further when my papers were given in to the royal society in 1754, it was judged that the platina had been dissolved by the sulphurated alcali, as most of the other metals are. The experiment however seeming on a revival not sufficiently satisfactory, I was going to repeat it with more attention, when Mr. Marggrafs memoir came to my hands, in which I find it repeated also by him.

Mr. Marggraf first mixed two ounces of pure salt of tartar, one ounce of sulphur, and half an ounce of platina; and set the crucible, with another inverted and luted on it, in a forge. After the fire had been vehemently excited for three hours, the Hessian crucible and its support, with part of the bricks of the forge, were found melted together, and on some fragments was seen platina, in form of little silver leaves, but not well cohering. The excess of heat having rendered this operation fruitless, it was necessary to make another trial.

Half an ounce of platina, half an ounce of flowers of sulphur, and an ounce of pure salt of tartar, in a crucible carefully luted as before, were urged in a strong fire for two hours. On opening the crucible, the matter appeared to have melted, looked yellowish on the outside, and when

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broken,

broken, shewed here and there some reddish crystals: it was leafy, like the mineral called by the Germans *eisenrahm*. Some hot water was poured on it, and more water added so long as the liquor received any tinge. The filtered *lixivium* was of a yellow-green colour like the common solution of hepar sulphuris. On washing off the lighter parts of the undissolved matter, the remainder looked exactly like the *eisenrahm*, being in form of broad flakes, and soft to the touch: it was also lighter than platina, and had not the least resemblance to it.

He mixed forty grains of this matter with an ounce of nitre, and threw the mixture by degrees into a red hot crucible: scarcely any detonation happened. The fire being kept up for an hour, with care to prevent the falling in of any pieces of coal, there was obtained a grey mass inclining to greenish, which being set to digest in distilled water, the fluid became presently like gelly. By diluting and washing the matter, he recovered, without alteration, the platina which he had believed to be destroyed.

This experiment appearing still indecisive, I made some further trials. I mixed four ounces of flowers of sulphur with the same quantity of pure fixt alkaline salt, and threw the mixture by little and little into a red hot crucible, covering the crucible after each injection. The mixture being in perfect fusion, an ounce of platina, which had been previously exposed to a strong fire by itself till the grains were united into a lump, was dropt in, and a moderate heat continued for three or four hours. The lump of platina was quickly divided, though the metal did not remain suspended in the sulphureous mixture, but subsided, at least in great part, to the bottom, from whence it was every now and then stirred and taken up with the bole of a tobacco pipe. The crucible at length cracked and was greatly corroded. The matter being boiled in about a  
quart

quart of distilled water, the filtered liquor was of a dark reddish colour: the remainder, boiled in fresh quantities of water, gave an olive-green tincture. The boiling being repeated, and the matter rubbed in a mortar, till it gave no more tinge to the water, the part which remained at last undissolved was a dark-coloured powder, which had nothing of the appearance of platina, but was found to be no other than platina divided. This platina was treated in the same manner with fresh hepar, three or four times: the crucibles always failed and were much corroded, and the platina was reduced into a powder so subtile, that it could not be separated by washing from the parts of the crucibles which were pounded with it.

I tried also a hepar made in Stahls manner, by melting vitriolated tartar with powdered charcoal. This mixture melted very easily, without any addition of the alkaline salt or common salt, which are generally thought necessary for promoting the fusion: for though vitriolated tartar is very hard of fusion by itself, yet here, its vitriolic acid uniting with the inflammable part of the charcoal into sulphur, the matter becomes a compound of sulphur and alkali, and melts as easily as the hepar made directly from those ingredients. Platina, treated with this hepar, suffered the same change as from the other. The crucibles were equally corroded: the watery solutions of the mass were partly reddish, and partly of an olive-green colour: the grains of platina, previously agglutinated into a lump by strong fire, were disunited, and in great part divided into a powdery form.

It appears therefore that platina is divided by hepar sulphuris in fusion, nearly in the same manner as by long cementation with nitre: it remains to examine whether any part of it was truly dissolved, so as to be taken up by the water along with the sulphureous alkaline mixture. I fil-

tered the liquors twice through double papers, and then added by degrees spirit of falt to neutralize the alcali: at first a brownish precipitate fell, and afterwards a white one like the common precipitated sulphur. A little of the brown precipitate was heated in a small scorifying dish, and some nitre added to burn off the sulphur more effectually: there remained on the dish several bright particles like platina, sprinkled all over its surface. The rest of the precipitate being burnt in like manner, I added some pure lead, to collect the dispersed particles of the platina, and afterwards worked off the lead in a cupel: it left a rough brittle bead, exactly like those obtained in cupelling crude platina with lead, of which an account will be given hereafter in the seventh section. It seems to follow from these experiments, that hepar sulphuris really dissolves platina, though very difficultly, and very sparingly.

#### XI. *Platina with earthy bodies.*

CERTAIN earthy bodies are found to promote the fusion, not only of some metallic minerals, but in some instances, of the purer metals also: thus forged iron, which could not be made to melt in a crucible without addition, was brought into fusion by surrounding it with gypsum or plaster-of-paris, a fact which we owe the discovery of to Mr. de Reaumur. To see if platina would be anywise affected by substances of this kind, I intermixed an ounce of it with gypsum, and urged it with a strong fire in a blast furnace for two hours: the Hessian crucible was corroded in many parts to the thinness of paper, and here and there quite through, the matter of the crucible and the gypsum having in some measure vitrified together; but the platina remained unmelted, and unaltered.

Quicklime, and calcined flint, were likewise made trial of in the same manner, but no change was produced by them in the platina.



XII. *Platina with vitreous bodies.*

1. HALF an ounce of a precipitate thrown down from solution of platina by tin, was ground in an iron mortar, with eight times its weight of common flint glass, and the mixture put into a crucible, which was covered and luted, and placed in a wind furnace. The fire was gradually raised, and kept up extremely strong for about ten hours: the crucible being then taken out and broken, the matter proved of a dark blackish colour, untransparent, friable, interspersed with a bright whitish substance apparently metallic. It is probable that this metallic matter was the platina, and that the glass owed its opacity and dark colour, not to this metal, but to tin in the precipitate, or some particles of iron worn off from the mortar, or other accidental causes.

2. I ground in a glass mortar a quarter of an ounce of a precipitate of platina made by alkaline salt, with twelve times its weight of powdered flint glass, and committed the mixture to the same fire as the foregoing. The result was a compact cloudy glass, pretty transparent in thin pieces, covered in part with a thin whitish coat. Towards the upper part, and all round the sides, were observed several particles of metal, which appeared to the eye like bright platina, and proved hard to the point of a knife. In this, as in the foregoing experiment, the glass seems to have received nothing from the platina, the change being no other than what flint glass is found to undergo from a slight introduction of inflammable matter.

3. Mr. Marggraf gives an account of three experiments of the mixture of platina with vitreous bodies. Five drams of pure salt of tartar, twelve drams of clean sand calcined and washed, one dram of calcined borax, two of nitre, and two of crude platina, were mixed together, and kept

kept in a vehement fire, in a close crucible, for several hours. The result was a vitreous, somewhat opal-like mass, inclining to a sea green: the platina, no otherwise altered than in being made whiter, was dispersed partly on the surface of the glass, and partly about the sides, and surrounded with a distinct vitreous matter of a deep hyacinth colour.

4. He tried also the powder separated from platina by cementation with nitre, as described in page 492. Six grains of this powder were mixed with a hundred and eighty grains of white sand, and ninety grains of salt of tartar. The mixture, melted with a vehement fire in a close crucible, proved a porous, greyish, untransparent glass.

5. He prepared a precipitate from platina and tin together, and tried to vitrefy this mixt. A polished plate of tin being digested in solution of platina, part of the platina precipitated upon the tin in form of a blackish red powder, and the tin, in some days, was quite corroded: the liquor, of a dark coffee colour inclining to black, being put into a filter, run through blackish. This compound solution of platina and tin was precipitated with salt of tartar: the liquor now passed the filter colourless, and the matter which remained on the paper, being well washed with hot water and dried, was a black substance, almost resembling, in its fracture, broken pitch or fine pit-coal. Forty grains of this substance, sixty of calcined borax, a hundred and twenty of purified nitre, two hundred and forty of pure salt of tartar, and four hundred and eighty of powdered flint, were well mixed together, and melted in a very strong fire. They yielded a greyish glass, in which no metallic grains could be found: a thin piece of the glass, laid upon the nail and held up to the sun, inclined to an amethyst colour.

It

It does not appear from these experiments, that any part of the platina was truly vitrified. We may rather conclude, that the disappearance of the platina in the two last experiments was owing to its being diffused through the mass in a state of powder too subtile to be distinguished: the colour of the glass cannot be ascribed to the platina, since No. 3. afforded colours more considerable, though the grains of platina remained unaltered.

6. In my experiments, No. 1 and 2, particularly in the latter, the platina, though it had been attenuated by solution and precipitation before its mixture with the vitrescible ingredients, separated from the glass in fusion, and was collected into very sensible particles, some of which were of considerable magnitude. In an experiment of Mr. Macquers, this effect was still more strongly marked. The red precipitate of platina made by alcalies was mixed on a porphyry stone with a flux composed of one dram of calcined borax, one dram of creme of tartar, and two drams of a white glass, which he had himself prepared from six parts of white sand and eight parts of borax: the proportion of the precipitate of platina to this flux he does not specify. The mixture was urged with the fire of a forge, animated by several bellowses, for thirty-five minutes, and the matter being then in good quiet fusion, it was suffered to cool. The upper part of the mass was a blackish glass: at the bottom of the crucible was found a well collected lump of platina, pretty brilliant and smooth on the surface, weighing ninety-six grains. This lump had all the appearance of a metal that had received a very good fusion: nevertheless, on trying to extend it under the hammer, it broke in two pieces, and shewed an oval chamber or cavity in the middle: the fracture resembled that of large-grained brittle iron: in hardness it was nearly equal to forged iron, for it scratched deeply gold, silver, copper, and even iron itself.

itself. The texture, brittleness, and cavity in the lump shewing that the platina, though it had approached considerably towards fusion, had not melted perfectly, the author proposes to repeat the operation with a degree of fire still stronger.

It must be observed on this experiment, that in the precipitate made use of, the platina cannot be supposed to have been pure from other metals. Solutions of platina plainly contain iron, as appears from their striking a blue colour with the Prussian alkali: either fixt or volatile alcalies precipitate this iron along with the platina; and as part of the platina remains dissolved, the precipitate may contain a greater proportion of iron than the grains of platina itself did. Though the iron is in a state of calx, dissoluble by the glass, and not miscible with metallic bodies in their perfect state; yet a slight introduction of inflammable matter is sufficient to revive it, calces of iron seeming to be easier of revival than those of any other metal. The black colour of the glass was owing doubtless to the iron; nor would it be surprising, if preparations of platina should on further trials be found to tinge glass of all the colours that iron can communicate. If the platina really melted, the fusion may be ascribed to a mixture of the same metal: but most probably the appearance of fusion was no other, than a conglutination of the impalpable atoms into which the platina had been divided, similar to what we find to happen when the crude mineral is urged with a strong fire.

From the experiments related in this section it appears, that platina is not only of itself refractory in the fire; but obstinately resists the additions, and managements, by which every other known metallic body is corroded, dissolved, or changed to a vitreous state. If, as the chemists teach, metals are the more perfect, in proportion as they are the more permanent and the less susceptible of changes, platina is of all known metals the most perfect.

## S E C T. V.

*Of the mixture of platina with metals.*

THE advantages which this new metal receives from its permanence and untarnishing whiteness, and from its resistence to liquids by which most of the other metals are corroded or dissolved; are in great measure rendered ineffectual, by its wanting the fusibility, which might enable the workman to form it into vessels or utensils. We have little foundation to expect any uses of this kind, from so refractory a body, unless in combination with other metals; some of which may, perhaps, either have their own qualities improved by the admixture of certain proportions of it, or serve as intermediums for uniting the parts of the platina, without much injuring it in regard to those properties in which its excellence consists. These hopes contributed to animate me in the prosecution of a laborious set of experiments, which however, independently of such considerations, could not fail of affording interesting phenomena. I regret that throughout this section, I have little more than my own trials to relate: Marggraf and Macquer have not entered into this enquiry, and Scheffer could proceed in it but a little way for want of platina to work upon. From the united labours of such hands, discoveries of more importance may result.

As platina is to be dissolved by the melted metals, we shall apply to it the several metallic bodies nearly in the order of the facility with which they become themselves fluid in the fire; beginning with the singular one which we find naturally in a state of fusion.

I. *Platina with Quicksilver.*

ONE ounce of platina and six ounces of pure quicksilver were rubbed together, with a little common salt and water and a few drops of spirit of salt, in an iron mortar. After the grinding had been continued about six hours, the grains of platina appeared coated with the quicksilver, so as to cohere together into a kind of imperfect amalgam. The fluid quicksilver being poured off, I evaporated part of it in an iron ladd: it left a considerable quantity of a dark-coloured powder, intermingled with shining particles. A part of the quicksilver was passed through a linen cloth, and a part was strained through thin leather: both these left also on evaporation a like powder, the quantity of which was pretty considerable from the portion which had been strained through the linen, but very small from that which had passed through the leather.

Mr. Scheffer also tried the amalgamation of platina with mercury, and reports that it did not succeed, though the grinding was continued, with the addition of a little aqua regia, at least twice as long, as is requisite for the amalgamation of iron filings with mercury when solution of green vitriol is added. It appears from the above experiment, that great part of the platina, even after long grinding, remains still in entire grains, not dissolved or combined with the mercury into such a mass as is called an amalgam: but the adhesion of the mercury to the surface shews an affinity between the two, or a disposition to unite; and the powder left upon evaporating the strained quicksilver is a proof that some part of the platina was truly dissolved. I repeated the experiment several times, and always found that a part of the platina was dissolved by the mercury, and that the undissolved grains were coated with it.

II. *Platina*

II. *Platina with Bismuth.*

A MIXTURE of black flux and common salt being brought into fusion in a crucible, equal parts of platina and bismuth were dropt in, and urged with a quick fire strongly excited by bellows. The two metals appeared to have melted together in a few minutes; and the crucible being then taken out of the fire and cooled, the metallic lump at the bottom, freed from the flux, was found to weigh nearly as much as the ingredients did at first, the loss being only about one part in a hundred and twenty. On breaking it, no grain of platina could be seen, this metal seeming to be all dissolved and blended with the bismuth.

The experiment was repeated in a wind furnace, but in this gradual heat the two metals did not well unite; nor was the union here perfect till the bismuth was increased to about thrice the weight of the platina. By larger quantities of bismuth, the platina was very easily dissolved in the wind furnace as well as in the blast furnace; but in all cases a part of it subsided if the mixture was suffered to cool slowly.

I melted platina with different proportions of bismuth, as far as twenty-four parts of the latter to one of the former. All the compositions proved, like the bismuth itself, extremely brittle: one was not remarkably more or less so than another. To the file, they were scarcely harder than pure bismuth. On breaking them, the surface of the fracture appeared for the most part composed of striæ and narrow plates ranged transversely: with the larger proportions of bismuth, the striæ and plates were coarse and irregular; with the smaller proportions, finer; and when the two metals were in equal quantity, they could scarce be distinguished at all. When the masses were newly broken,

they looked bright and sparkling; except the compositions with a large proportion of platina, which were of a dull greyish colour, without any brightness. In the air they all tarnished in a remarkable manner, changing to a yellowish, a purplish or bluish, and at length to a purplish black: every one of them has suffered these changes, though some more slowly than others.

### III. *Platina with Tin.*

1. EQUAL parts of platina and pure tin were dropt into a mixture of black flux and common salt in strong fusion, and urged with a quick fire in a good blast furnace. After a few minutes, the two metals appeared perfectly melted; and being instantly poured out, they run freely along a narrow mould, forming a smooth ingot, nearly of the same weight with the platina and tin employed. The compound proved extremely brittle, breaking easily from a fall. When broken, it appeared of a close and smooth, though uneven, surface, and of a dull dark colour. By the file, or a knife, it was readily scraped into a blackish dust.

2. One part of platina and two of tin, covered with black flux, borax, and common salt, were melted in a wind furnace: the platina appeared perfectly taken up by the tin, soon after the fire had been raised to a light white heat. The ingot was found deficient in weight about one ninthieth part. It greatly resembled the foregoing, being only a little less brittle, and of a somewhat lighter colour.

3. One ounce of platina and four of tin, covered with black flux and common salt, and urged with a quick fire, melted together, with scarcely any loss. This compound stretched a little under gentle strokes of a flat hammer, but was by no means tough. It broke in pieces from a rude blow, and was readily scraped into dust by a knife. The broken surface was rough, and of a granulated texture.

4. One



4. One ounce of platina and eight of tin, dropt into a fluid mixture of black flux and common salt, united, without loss, into a pretty tough compound; which bore to be considerably flattened under the hammer without breaking, cut smooth with a thin chisel, and shaved with a knife. Broken, it appeared of a sparkling, dark coloured, coarse grained texture.

5. One part of platina and twelve of tin, treated in the same manner, formed a mixture tolerably ductile; but still of a dull dark hue, and a rough coarse grain, though less so than the preceding.

6. A mixture of one part of platina and twenty-four of tin, stretched under the hammer almost as easily as tin itself, but broke much sooner on bending. The colour was whiter, and the grain finer and evener, than those of the preceding compositions, though in both respects it fell considerably short of pure tin.

7. Several of these compositions, covered with black flux which had been previously melted by itself, till it ceased to boil up, were exposed, in crucibles closely luted, to a strong fire in a wind furnace, which was steadily kept up for eight hours. When taken out, they were all found to have suffered some diminution of weight, amounting to about one fortieth part of the tin. In their appearance and quality, there did not seem to be any alteration, except that the grain was a little finer, and the texture rather more uniform.

The foregoing mixtures seem to include a sufficient latitude, in the proportions of the two metals, for discovering their general effects on one another. We may infer from them, that within this latitude, platina diminishes the malleability of tin, renders its texture coarser, and debases its colour, more or less according as the platina is in greater or less proportion; and that, when the platina  
amounts

amounts to about one third of the tin or upwards, the malleability, which both metals separately possess, is destroyed by their combination with one another. The difference in the colours of these compositions was not so conspicuous on the touchstone, as when the fractures of the ingots were examined; although, on close inspection, the marks on the stone also appeared all of a darker colour than those of pure tin, and the more so as the proportion of platina prevailed in the mixt. Kept in a close room, in pill-boxes, they all tarnished in the fracture to a yellowish hue; but pieces which were ground and polished have in ten years suffered little change, except only the mixture of equal parts of platina and tin, which is grown considerably dull and yellow.

It is observable, that though tin is a metal very readily destructible by fire, yet in most of the foregoing fusions there was scarcely any loss of weight. This may be attributed in part to the admixture of the platina preventing the scorification of the tin; and in part to the flux made use of, and the celerity and short continuance of the heat. No. 2 and 7, where the heat was slowly raised and long continued, were the only ones in which the loss was at all considerable.

#### IV. *Platina with Lead.*

I. EQUAL parts of platina and lead were injected into a mixture of black flux and common salt previously melted together, and the fire raised hastily by bellows. A much stronger heat was requisite than for the fusion of platina with an equal quantity of tin, and the loss was considerably greater, amounting to about one sixty-fourth part of the metallic mixture. The metal yielded difficultly to the file, broke from a moderate blow, and appeared, on the fracture, of a close texture, an uneven surface, and rough jagged edges. The colour was very dark, with a faint purplish cast.

2. One part of platina and two of lead, covered with black flux and borax, and exposed to a gradual fire in a wind-furnace, did not come into due fusion till the fire had been raised to a strong white heat. From the long continuance of the fire in this experiment, the loss was great, amounting to nearly one twenty-fourth part of the mixture. The ingot proved hard and brittle like the preceding, but the texture striated, and the striæ disposed transversely.

3. One ounce of platina and three of lead, treated in the same manner, required still a very strong fire for their perfect fusion, and lost about one twenty-sixth. The metal broke less easily than either of the preceding, and in some measure stretched under the hammer. Its colour was somewhat darker, and inclined more to purplish.

4. One part of platina and four of lead being covered with black flux and common salt, and committed to a wind furnace, the platina still did not appear perfectly taken up till the fire had been raised to a considerably strong white heat: the loss was about one fortieth. The same proportions of the two metals, dropt into a fluid mixture of the flux and salt previously brought to the above degree of heat, quickly melted, and lost only one part in a hundred and sixty. The ingot was much tougher than the preceding, filed well, and cut tolerably smooth with a knife. On breaking, the upper part appeared composed of bright plates; the lower, of dark purplish grains.

5. One part of platina and eight of lead united easily in a quick fire, and lost little or nothing. The metal worked, and looked, like very bad lead. On breaking it, the texture appeared partly composed of transverse fibres, and partly of grains; its colour was dull and purplish.

6. One part of platina and twelve of lead united without loss into a compound very little different from the preceding.

preceding. Its texture was finer, and composed chiefly of transverse fibres, with very few grains.

7: A mixture of one part of platina and twenty-four of lead proved not very much harder than lead of a middling quality. The colour was still somewhat purplish, and the texture fibrous; but the fibres were remarkably finer than when the platina was in greater proportion.

8. The four first of the foregoing compositions, when newly polished, appeared of a dark iron colour, which quickly tarnished to a brownish yellow, a deep purplish, and at length to a blackish. The three last, cut with a chisel, looked of a leaden hue, which tarnished but little; though the fractures, and outer surfaces, of all the seven have changed nearly to a like purplish black.

9. Upon returning these compounds to the fire a second time, it was constantly observed, after they had come into perfect fusion, that if the heat was slackened a little, great part of the platina subsided: that nevertheless, the lead decanted off even in a heat below ignition, retained so much of the platina, as rendered it of a fine fibrous texture and purplish colour.

10. The several mixtures, covered with black flux, and kept in strong fusion, in crucibles closely luted, for eight hours, suffered a diminution in weight, amounting, in most of them, to about one thirtieth part of the lead. On breaking them, those with a large proportion of platina appeared of a leafy, and those with a smaller of a fine fibrous texture, which seemed in general to be characteristics of the perfect union of the platina and lead. They all looked whiter and brighter than at first, but tarnished sooner in the air. One mixture in particular, of four ounces of platina and twelve of lead, broke into large, white, shining, talk-like flakes; which, on exposure to the air, changed in a very little time, in less than an hour, to a reddish,  
a purple,

a purple, and a deep blue, and at length turned slowly to a dark purplish black colour.

The relations of platina to tin and lead appear therefore to be very different. Though a small proportion of it is taken up and kept suspended by lead in a very gentle heat; a large proportion is not near so readily dissolved as by tin, and, when united by a strong heat, subsides in great part upon the abatement of the heat. A little quantity stiffens and hardens lead more than it does tin, but a large one does not near so much diminish its malleability: a mixture of equal parts of platina and lead, though it has nothing of the ductility which each of the metals has separately, is much less brittle than the mixture of equal parts of platina and tin. But the most remarkable phenomena in the mixtures with lead are the leafy or fibrous texture, and a purplish or bluish colour or a disposition to acquire these colours speedily in the air, and the black to which they at length change. Bismuth, as we have already seen, exhibits with platina nearly the same appearances, though in a somewhat lower degree; and as none of the other metallic bodies I have tried was found to affect, or be affected by, platina in this manner, these experiments may be added to those of Mr. Geoffroy, in one of the late volumes of the memoirs of the French academy, for establishing an analogy between bismuth and lead.

#### V. *Platina with Arsenic.*

WHITE arsenic is a volatile metallic calx, reducible to its metallic form by exposing it to a moderate fire with inflammable additions. A mixture of white arsenic and fixed alkaline salt, of each one ounce, with two ounces of powdered charcoal, was pressed smooth into a crucible, and one ounce of platina spread above it: the crucible was closely covered and luted, and kept for twelve hours in a

X x x

moderate

moderate cementing heat, which towards the end was increased to a considerable degree. On separating the platina from the mixture by washing, many of its grains appeared divided, and its weight was somewhat increased. Being afterwards exposed hastily to a very intense fire, it did not melt, but emitted arsenical fumes, and after these had ceased, the platina was found to weigh just one ounce as at first.

This experiment seeming to shew that platina and arsenic have some disposition to unite, I was preparing to prosecute it, to see if more arsenic could be combined with the platina so as to bring it into fusion, when Mr. Scheffers papers came into my hands, in which I find a remarkable experiment on this point. Mr. Marggraf likewise has since tried platina with arsenic, in a manner not greatly different from that above mentioned.

Mr. Marggraf mixed one dram of platina with two drams of white arsenic, and exposed the mixture to the fire in a glass retort: the arsenic rose uncoloured, and left the platina white and undiminished in weight. The process was repeated with the same quantity of fresh arsenic, and the fire augmented to as great a degree as the coated retort could bear: the arsenic still rose white, but the grains of platina were now become black, though they still continued malleable, and weighed as much as at first. A dram of platina, two drams of arsenic, and one dram of sulphur, being well mixed together and treated in the same manner; the arsenic and sulphur subliming together formed, as they usually do when united in these proportions, a red compound; the platina becoming blackish, and weighing two grains, or one thirtieth part, more than at first. It seems therefore that in this way of managing the process, the arsenic has less effect on the platina than in my experiment above mentioned.

Mr.

Mr. Scheffer proceeded in a different manner. The platina was first strongly heated in a crucible by itself, and a little arsenic being then thrown upon it, they immediately melted together. He observes, that platina melts with arsenic as easily as copper and iron do when they are blended with arsenic; that there is no occasion for any flux; that one part of white arsenic is sufficient for four and twenty parts of the platina; and that the platina thus melted with arsenic is quite brittle, and breaks grey like arsenicated silver.

On repeating this experiment it appeared, that though the judicious author is by no means chargeable with any mistake, yet the little quantity of platina, he had to allow for the trial, made it impossible for him to discover the limitations, with which this strong action of arsenic on platina ought to be understood. When only a few grains of platina are used, there is all the appearance of true fusion, but on taking larger quantities we frequently find the fusion to be only superficial and imperfect. An ounce of platina was strongly heated in a crucible, and pieces of white arsenic repeatedly thrown upon it, the arsenic amounting in all to near as much as the platina: some of the grains melted into round drops: the greater part cohered into a mass, differing from those, into which platina itself is formed by fire, in the surface being smooth and uniform, and the grains in the internal part more firmly coherent. I treated another ounce of platina in the same manner, and with the same event: the mass was of a smooth surface, as if it had been perfectly melted, but its internal part was composed of grains of platina in their usual form. I put both masses into a crucible, with fresh arsenic mixed with powdered charcoal, and urged them with a strong fire for half an hour: they run into one lump, of the figure of the bottom of the crucible, exter-

nally smooth, and of a bright white colour like quick-silver, very brittle, internally greyish, of a spongy texture, with some few of the grains of platina left entire in the middle: the crucible was lined with a black glass, probably a vitrification of the ferruginous part of the platina; and several shining metalline globules adhered to the vitreous matter. The lump was again dropt into a strongly heated crucible, with more arsenic and charcoal powder, and the fire excited by the bellows for another half hour: it melted as before, into a cavernulous mass, in which no grains of platina could now be seen. It was again treated in the same manner with fresh arsenic, and tried to be poured out; but though the fire was made very intense, the metal would not run from the crucible. Being then urged in a quick fire without addition, it concreted into a lump of the same appearance as before: but a piece of this lump, dropt again into a crucible intensely heated, did not seem to soften or suffer any alteration of its figure. The rest of the lump was inclosed between two small pieces of charcoal, a cavity being made in each piece for receiving it: the charcoal was coated over with luting, and, when thoroughly dried, dropt in among the fuel before the nose of the bellows: the metal did not alter its figure, nor was its weight diminished: I took half an ounce of the metal, and arsenicated it again in the same manner as at first, adding at different times more and more arsenic: it run into a lump as before, but I could not, by any increase of the fire, or by any addition of arsenic, make it thin enough to flow from the crucible. I took half an ounce more of platina, and having combined with it as much arsenic as I could by repeated injections, I reduced the mass into gross powder, mixed it with black flux and some fresh arsenic, and urged it with a quick fire in a covered crucible: the metal run into a  
spongy



spongy lump, which retained particles of the flux here and there in its cavities, a mark that it had not flowed thin.

It appears upon the whole, that platina does melt with arsenic, but less perfectly than with other metals; and that it would be very difficult, if not impossible, to bring it, on this foundation, to sufficient fusion for being poured into a mould. All the arsenicated pieces are very brittle, internally of a greyish colour, and a loose granulated texture. It is observable that though arsenic soon changes in the air to a blackish hue, and when mixed with other metals disposes most of them to change in like manner, the arsenicated platina, after lying in a dry room for seven or eight years, continues nearly of the same appearance as at first.

#### VI. *Platina with Zinc.*

For uniting zinc with platina, I first tried the method in which zinc is commonly united with copper, and by which the zinc is at the same time purified from such other metallic bodies as are frequently blended with it; viz. exposing the platina to the fumes, extricated by fire and inflammable additions, from calamine, one of the purer ores of zinc. But that these fumes might act the more effectually on the platina, a little variation was made in the common manner of disposing the materials.

Four ounces of calamine in fine powder were mixed with two ounces of powdered charcoal. Having often observed that calamine, with this proportion of charcoal, acquires a kind of fluidity in the fire, so that the platina would be apt to sink through it to the bottom; I made the powder into a mass with a little thin tempered clay, and pressed it into the bottom of a crucible: above this mass, the crucible was lined all round with luting to a considerable thickness, so as to leave only a small passage in the middle for the fumes of the zinc to issue out; in  
which

which passage, when the luting was thoroughly dried, an ounce of platina was placed. The crucible was covered and set in a wind furnace, and a pretty strong fire kept up for six hours. Being then taken out, some flowers of zinc were found adhering to the cover, greatest part of the platina was melted into small bright globules, and such grains, as retained their figure, appeared frosted over with minute globular protuberances, as if they had just begun to melt. Its weight was increased above a third part, so that it had imbibed about as much of the zinc as copper does in the common process of making brass.

Finding the fumes of zinc to act so powerfully on platina, I next tried zinc in its common metallic form. Upon an ounce of platina, covered with borax, and heated in a blast furnace to a strong white heat, I threw an equal quantity of zinc. A violent deflagration arose, and the platina seemed to be almost instantly dissolved. The metal, being immediately poured out, run freely into the mould, and was found to have lost near half an ounce in weight; so that the quantity of zinc, which had sufficed to keep the platina in good fusion, was very little more than one half of the platina.

I made several further trials of the same kind, with different proportions of the two metals, both in a quick fire in a blast furnace, and in one more gradually raised in a wind furnace: the zinc always proved a strong menstruum for the platina, though much of the zinc was dissipated by the heat requisite for rendering the mixture sufficiently fluid. One ounce of platina and four ounces of zinc being melted together in the blast furnace, as in the above experiment, the loss was an ounce and a half, so that there remained with the platina about two ounces of the zinc. This compound was dropt upon another ounce of platina, strongly heated as before with borax: the metal,  
poured

poured out, run clean from the crucible, and weighed just two ounces and a half, so that the platina was here kept in fusion by one fourth its quantity of zinc. This mixture was put into the same crucible, with the same borax: it still deflagrated, melted, and on being poured into an iron ingot-mould, which had been newly smoked over the flame of a torch but not heated, the fluid metal was thrown about with violence in small drops: this probably happened, not from any particular qualities of the metal, but from some moisture in the mould.

Compositions of platina with different proportions of zinc differed little in appearance from zinc itself; except that where the quantity of platina was large, they were of a closer texture and duller hue, with rather more of a bluish cast. Kept for ten years in a dry room, they do not seem to have tarnished or changed their colour. They were much harder to the file than zinc itself, and fell in pieces under the hammer; without at all stretching, as pure zinc does in a considerable degree. One twentieth of platina destroyed the malleability of zinc, and one fourth of zinc destroyed the malleability of platina: within this compass, we have no degree of ductility to expect from any mixture of the two.

#### VII. *Platina with Regulus of Antimony.*

EQUAL parts of platina and regulus of antimony were dropt into a fluid mixture of black flux and common salt, and the fire strongly excited by the bellows. They melted perfectly together, and run freely into the mould. The compound looked of a much duller colour than the regulus at first, and, when broken, shewed a close and uniform, though uneven surface: it proved considerably harder to the file, but not remarkably more or less brittle under the hammer.

One.

One part of platina and twenty of regulus of antimony being treated in the same manner, the compound looked brighter, and of a leafy texture, little different from that of the pure regulus.

The two metals were melted together in several of the intermediate proportions, but no other differences were observed than those abovementioned; the mixtures with a large proportion of platina being of a dull colour and close texture, and those with a small one bright and leafy. All of them continue untarnished.

Though the platina and regulus seemed to unite very well together, yet in slow cooling, part of the platina was apt to subside. Six ounces of platina and twenty-four of regulus of antimony having been melted together with a quick fire, and poured into a mould, the compound appeared uniform throughout. Being melted again, kept in steady fusion for five or six hours, and suffered to cool gradually in the furnace; the upper part of the mass was bright, and of a large leafy texture, much like the regulus at first; the bottom was much duller and of a closer texture, and contained apparently a much larger proportion of the platina.

#### VIII. *Platina with Silver.*

I. TWENTY grains of platina, and the same quantity of pure silver which I had revived from luna cornea, were covered with borax, and urged with a vehement fire in a blast furnace. They melted difficultly together, and did not prove fluid enough to run freely along the mould. The metal weighed thirty-nine grains, and on the sides of the crucible were seen several small particles, amounting, as nearly as could be judged, to about a grain more, so that there appeared to be no loss of weight. The compound was hard to the file, and broke from a rude blow, though by gentle strokes

strokes it bore to be considerably flattened. Internally it appeared of a much duller and darker colour than silver, and of a much coarser grained texture.

2. One part of platina and two of silver, covered with nitre and common salt, did not flow thin till the fire was raised to a strong white heat, and, when poured out, left many small particles adhering about the sides of the crucible. The metal proved less brittle than the foregoing, and not so hard to the file: its texture was finer grained, and the colour whiter.

3. One part of platina and three of silver required also a very strong fire for their perfect fusion, and many particles of the metal were thrown up almost to the top of the crucible, as if the action of the silver upon the platina had been accompanied with a kind of ebullition or explosion. The compound was hard and brittle, though less so than the preceding: by repeated nealing, it bore to be hammered, or flatted between steel rolls, into thin plates.

4. One part of platina and seven of silver melted together pretty easily, but a part of the metal was thrown up about the crucible as before. The compound hammered tolerably well, proved much harder than silver, and not so white, nor of so fine a grain.

5. In the foregoing experiments, the quantity of platina was from ten to twenty grains. I tried sixty grains of platina with four times, eight times, twelve times, twenty times, and thirty times as much fine silver. One of these mixtures was treated without any flux, another was covered with borax, another dropt into borax previously brought into fusion, another into melted black flux, and the last into melted common salt: the fire was strongly excited by the bellows, and all the mixtures suffered to cool in the crucibles. With these larger quantities of the two metals, the phenomenon above taken notice of was

more remarkable: Numerous metallic globules appeared all over the insides of the crucibles, and many on the covers also: the differences in regard to the fluxes, and in the proportions of the two metals, seemed to make no material difference in this respect. Some of the mixtures were melted over again, in fresh crucibles, several times: the metal sparkled up in the same manner every time. On pouring them into moulds, unless the heat was very intense, a considerable part remained behind, the silver seeming to quit the platina on an abatement of the heat. When the heat was so strong that the whole ran fluid into the mould, great part of the platina separated and fell to the bottom in cooling, unless when the mould was very broad, so that the compound began to fix almost immediately, without allowing time for the platina to subside.

6. I likewise melted silver with different proportions of a precipitate of platina obtained by adding mercury to a solution of platina in aqua regia. Here also the event was the same: the metal spattered up in extremely minute grains, which seemed as it were to penetrate the crucible.

7. There appears upon the whole a strong repugnance between platina and silver. Mr. Scheffer takes notice also of the difficulty of uniting these two, though the sparkling up of the metal, which was not considerable in my experiments when the quantities were small, does not seem to have been perceived at all in his. He observes that platina melts more difficultly with silver than with lead or copper; that three parts of silver are necessary for making one part of platina melt by a blow pipe; and that the mixture retains the whiteness which both metals possess, but proves hard and brittle. In all my mixtures with large proportions of platina, the colour was greatly inferior to that of silver: besides being very dull, they had somewhat of a yellowish cast; and this yellowishness continued sensible

even

even when the silver amounted to twenty times the weight of the platina ; but one part of platina with thirty of silver made a mixture as white as the silver itself. None of them seem to have tarnished or changed their colour in keeping.

#### IX. *Platina with Gold.*

THE near and remarkable relation betwixt platina and gold in many properties hitherto supposed to belong to gold alone, their as manifest disagreement in others, and the reports of gold having been debased by the admixture of considerable quantities of platina, induced me to examine more particularly the effects of these two metals in combination with different proportions of one another. The proportions were adjusted according to the carat weights, as explained in the seventh section of the history of gold, the fineness of gold being usually expressed in carats and their subdivisions. The absolute weight of what in these experiments is called a carat, was four grains.

1. Twelve carats of fine gold, and the same quantity of the purer grains of platina, were urged in a blast furnace for near an hour, with a fire so strong, that the slip of Windsor brick with which the crucible was covered, though it had been dipt in thin tempered Sturbridge clay, begun to melt. Upon breaking the vessel, the metal was found in one smooth lump or bead, which being nealed by the flame of a lamp, and boiled in alum water (the liquor commonly used by the workmen for cleaning or brightening masses of gold and silver) appeared, both in the mass and upon the touchstone, of a pale bell-metal colour, without any resemblance to gold. It bore several strokes, and stretched considerably under the hammer, before it began to crack about the edges. On viewing the fracture with a magnifying glass, the gold and platina ap-

peared unequally mixed, and several small particles of the latter were seen distinct: nor was the mixture entirely uniform after it had been again and again returned to the fire, and suffered many hours of strong fusion.

2. Eighteen carats of gold and six of platina were melted together as the foregoing, in an intense fire continued about an hour. The bead, nealed and boiled, was less pale coloured than the former, but had nothing of the colour of gold. It forged tolerably well, like coarse gold. To the naked eye it appeared uniform; but a good magnifying glass discovered, in this as well as in the other, some inequality of mixture, notwithstanding the fusion was two or three times repeated, with as great a degree of heat as we could easily excite by the bellows.

3. Twenty carats of gold and four of platina were kept in strong fusion above an hour and a half. These united into an equal mass, in which no granule of platina or dissimilarity of parts could be distinguished. The colour was still so dull and pale, that the compound could scarcely be judged by the eye to contain any gold. It hammered well into a pretty thin plate, but we could not draw it into wire of any considerable fineness.

4. Twenty-two carats of gold were melted in the same manner with two carats of platina, the same proportion that standard gold contains of alloy. The mixture was uniform, and had a good deal of a golden colour, but with a particular dull dark hue, by which the eye could at once distinguish it, not only from fine gold, but from all the common sorts of alloyed gold. It worked well, was forged into a thin plate without cracking, and drawn into moderately fine wire.

5. Twenty-two carats and a half of gold and one and a half of platina, or fifteen parts of the former to one of the latter, melted into an uniform mass, which after the usual  
nealing



nealing and boiling, proved somewhat tougher than the preceding, and of a better colour.

6. Twenty-three carats of gold were melted with one of platina, which is nearly half the proportion that standard gold contains of alloy. The compound worked extremely well; but was distinguishable from fine or standard gold by some degree of the ill colour of the two foregoing, which it retained after repeated forgings, fusions and boilings.

7. Twenty-three carats and one fourth of gold, and three fourths of a carat of platina, or thirty-one parts of the former to one of the latter, formed an equal mixture, very malleable, ductile like the three foregoing while hot as well as cold, but not altogether free from their particular ill colour.

8. A mixture of twenty-three carats and a half of gold with half a carat, or one forty-seventh its weight of platina, was very soft and flexible, of a good colour, without any thing of the disagreeable cast by which all the foregoing were readily distinguishable by the eye from any kind of alloyed gold I have seen.

9. A mixture of twenty-three carats and three fourths of gold with one fourth of a carat, or one ninety-fifth its weight of platina, could not be distinguished, by the eye or the hammer, from the fine gold itself.

10. In all the above processes, even where the quantity of platina was very small, the fusion was performed with a vehement fire, that the platina might be the more perfectly dissolved, and equally diffused through the gold. This appeared to be a very necessary precaution. Having once melted gold with one fourth its weight of platina, the button appeared not much paler than standard gold with silver alloy, but on a second fusion it lost its yellowness, and looked not much unlike bell metal. The gold  
colour

colour appeared to have been only superficial, from an imperfect mixture; most of the platina having been concealed in the internal part of the mass, and covered as it were with a golden coat.

11. In some circumstances I have seen the gold, after it had been thoroughly mixed with the platina, spued out again in part to the surface. The foregoing bell-metal coloured mixture, after repeated fusions with and without additions, and in different degrees of heat, became once yellow on the surface. On cupelling mixtures of platina and gold with lead, I have oftener than once seen the remaining button covered with a golden skin, and all the internal part grey.

12. In melting the platina and gold together, a little borax was always used as a flux; with an addition of nitre, which somewhat heightens the colour of gold, or at least prevents the borax from making it pale. Pieces of some of the mixtures were remelted, with borax alone, with nitre alone, with common salt, with fixt alkaline salt, and with powdered charcoal: those with borax seemed to be the palest, and those with charcoal powder the best coloured, though the differences were very inconsiderable.

13. As a small portion of copper somewhat heightens the colour of pale gold, I melted platina with eight times its weight of standard gold made with copper alloy; that is, three parts of platina with twenty-two parts of fine gold and two of copper. The fusion was performed, as in the preceding experiments, with a strong fire, in a close crucible, but without any flux, and continued about an hour. The metal appeared covered with a black scurf, and had lost about a two-hundredth part of its weight. It was much duller coloured, much harder under the hammer, and cracked sooner about the edges, than mixtures of fine gold with considerably larger quantities of platina. By  
repeated

repeated fusion and frequent nealing, it became a little softer and tougher, so as to be drawn into pretty fine wire; but the colour was still exceeding dull, more resembling that of very bad copper than of gold.

It appears from these experiments, that platina diminishes the malleability of gold much less than it does that of the other malleable metals; and infinitely less than lead, tin, iron, and the brittle metals do that of gold: that in considerable proportions it debases the colour of gold far more than the usual alloy, communicating a peculiar and remarkable ill colour; and that it both hardens, and debases the colour of standard gold, with copper alloy, much more than fine gold: that in small proportions, as one forty-seventh and downwards, it does not sensibly injure either the colour or malleability of gold; and consequently, that large proportions of platina mixed with gold are discoverable at sight, but that small proportions, if perfectly united with the gold, will not betray themselves either to the eye or in the workmans hands.

#### X. *Platina with Copper.*

1. EQUAL parts of platina and copper, exposed, without addition, to a strong fire hastily excited by bellows, soon became fluid, but not thin; and lost about one sixty-fourth. The metal proved extremely hard to the file, broke difficultly on the anvil, flew asunder upon endeavouring to cut it with a chisel, and appeared internally of a coarse grained texture and white colour.

2. One ounce of platina and two of copper, urged with a quick fire in a blast furnace, without addition, flowed sufficiently thin, and scarcely suffered any loss. The metal was still very hard, and stretched but little under the hammer. It looked darker coloured than the foregoing, with a slight reddish cast.

3. One.

3. One ounce of platina and four of copper, treated in the same manner, united without loss into a pretty tough compound, which bore to be considerably flattened, cut with a chisel, and bent almost double before it cracked. Internally it looked of a fine texture, and of a very pale copper colour.

4. A mixture of one ounce of platina and five of copper stretched somewhat more easily under the hammer than the preceding, and appeared of a redder colour.

5. Upon increasing the copper to eight times the quantity of the platina, the compound proved sufficiently tough, broke difficultly, and hammered well. It was much harder than copper, and of a paler colour.

6. A mixture of one part of platina and twelve of copper was somewhat more easily extended under the hammer than the preceding, and proved softer to the file. It stuck a little in the teeth of the file, which the compositions with a greater proportion of platina did not.

7. A mixture of one part of platina and twenty-five of copper was still somewhat paler coloured than pure copper, and considerably harder and stiffer, though very malleable. On increasing the copper a little further, the mixture continued somewhat harder than the copper by itself, and appeared of a fine rose colour.

8. In the foregoing fusions, though in general no flux was made use of, there was scarcely any loss of weight, except in No. 1, where the large proportion of platina required the fire to be raised to a violent degree. This seems owing in great measure to the platina preventing the scorification of the copper: for on melting pure copper, a great number of times, both with and without fluxes, there was constantly some loss.

9. The mixtures with large proportions of platina are difficultly extended under the hammer when cold, and when

when red hot they fly in pieces: they bear a good polish, and do not seem at all tarnished in keeping ten years; of the mixture of equal quantities in particular, the polished part continues very brilliant. No. 7. has tarnished a little, but seemingly not so much as pure copper.

Platina appears therefore from these experiments to harden copper, to dilute its colour, and diminish its disposition to tarnish; in small proportions, to improve its hardness, without much injuring either the colour or malleability; and in larger proportions, to injure the malleability less than it does that of any of the other ductile metals, except gold and perhaps silver. Platina and copper seem to form valuable compositions, of which I doubt not but the workman may avail himself.

In a letter from Spain to a person in London, a translation of which has been communicated to me, there is an account of an experiment on platina and copper, which, though imperfectly related, may deserve to be mentioned here. The author first tried platina with an equal weight of silver, and found them to melt together . . . he afterwards melted it with copper, which united perfectly well; but whether it was the platina itself, or the mixture with silver, that was melted with the copper, is not clear from the words, though it seems to have been the former. The mixture with copper, “on trying to hammer it, flew about like glass; but having melted it over again with a stronger fire for some time, and thrown in a little saltpetre, mercury-sublimate, and other corrosives, it became malleable, and was then made into rings, which were worn for a good while without soiling the fingers, and preserved always the same colour and lustre as those called in Spanish *tombagos*, which consist of two parts of copper and one of gold.”

A mixture of equal parts of platina and copper (No. 1. of the above experiments) was tried by Mr. Scheffer, who reports, that they melted as easily as copper by itself; and that the mixture proved tolerably malleable, as mixtures of gold with a like quantity of copper: in both these points, the little quantity he could allow for the experiment may be supposed to have occasioned some deception. He adds, that when this compound is urged by a strong blast impelled upon the surface, as in the purification of copper before the bellows, it throws out sparkles like iron in welding, and that these sparkles are found in form of round grains, which partake of both the metals; a phenomenon which gold does not exhibit with copper. After this operation, he found the mixture less malleable than before, like copper over-refined.

#### XI. *Platina with Copper and Zinc.*

1. EQUAL parts of platina and brass, covered with borax and exposed to a quick fire in a blast furnace, melted perfectly together, and suffered very little loss. The mixt was of a greyish white colour, filed hard like bell-metal, broke from a blow of the hammer without stretching or receiving any impression, and flew asunder upon endeavouring to cut it with a chisel. Internally, it appeared of an uniform fine grain, a close texture, and a darker colour than on the outside. It bore a very fine polish, which in ten years does not appear to have at all tarnished.

2. One part of platina and two of brass, melted together in a slow fire, lost about one thirty-sixth. The ingot was of a duller colour than the foregoing, with a faint yellowish cast. It filed softer, and broke less readily from the chisel, but cracked and fell in pieces under the hammer. It received a good polish, and continues untarnished.

3. One

3. One part of platina and four of brass, covered as before with borax, and exposed to a quick fire, melted together without loss. This compound proved yellower than the preceding, and softer to the file; it bore to be cut some depth with a chisel before it broke, and received some impression from the hammer, stretching a little, but soon cracking in various directions.

4. Upon increasing the brass to six times the weight of the platina, the compound appeared yellower, though still very pale. It proved softer to the file; and stretched more under the hammer, and received a deeper impression from the chisel, before it broke.

5. A mixture of one part of platina and twelve of brass was considerably paler, and much harder, than brass. It broke under the chisel; and cracked, before it had extended much, under the hammer. Both this and the two preceding compositions bore a tolerably good polish, and have not tarnished so much as brass by itself; though in both respects they fall short of No. 1 and 2.

## XII. *Platina with Copper and Tin.*

1. FIFTY parts of platina, seventeen of copper, and six of tin, covered with borax, became fluid in a strong fire, and suffered very little loss. The ingot proved considerably hard, so as scarce to be touched by the file; and very brittle, breaking from a moderate blow, of a rough surface, and dull bell-metal colour. It bore a good polish, and continues untarnished.

2. Platina and copper of each one ounce, and four ounces of tin, melted perfectly together, with little or no loss. This compound filed freely and easily, and bore to be cut with a knife, but broke readily on the anvil; the fracture was of an irregular surface, and a dull whitish colour. Polished, it looked like polished iron: the fracture

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soon tarnished to a yellowish hue; the polished part grew dull but retained its colour.

3. A mixture of platina and copper of each one part, and eight of tin, proved softer than the foregoing, and flattened a little under the hammer. Broken, it shewed a very irregular surface, composed of a great number of bright white plates. It did not polish well. The fracture soon tarnished; the polished part retained its colour.

### XIII. *Platina with Iron.*

1. HALF an ounce of platina and an ounce of iron wire were placed on a bed of gypsum in a Hessian crucible, and covered and surrounded with more gypsum: after being urged in a blast furnace with two pair of bellows for about an hour, the crucible was in great part vitrified, and a large hole made in its side, by which most of the metal had run out. The experiment was four or five times repeated, but a perfect union of the platina and iron could not be obtained, the crucible being corroded and vitrified by the gypsum before the iron flowed thin enough to dissolve the platina. It was observable that the iron, thus melted, proved very malleable; though some have thought that forged iron, brought into fusion, is of the same nature with common cast iron.

2. Cast iron and platina, of each three ounces, exposed without addition to a strong fire, united into a thick fluid, which, on adding an ounce more of the iron, flowed pretty thin. The black lead crucible having become too soft from the great heat, to admit of being lifted with the tongs, the metal was suffered to cool in it. On breaking it, the metal was found in one lump, not convex, but of a very concave surface: its weight was about one sixteenth less than that of the platina and iron employed. It proved excessively hard, so as not to be touched by the file, and yet



yet so tough, as not to be broken by repeated blows of a sledge hammer, from which it received some impression. Heated red, it broke easily, and looked internally of an uniform texture, not composed of bright plates as the iron was at first, but of very dark coloured grains which had no metallic lustre.

3. One ounce of platina being thrown upon four ounces of cast iron beginning to melt, and the fire kept up strong, the whole came quickly into fusion. The compound, like the foregoing, was extremely hard, and seemed to stretch a little under the sledge hammer, without breaking. The texture was grained, as before, but the colour somewhat less dark.

4. One part of platina and twelve of iron melted without difficulty, and with little or no loss. This mixture also was much harder than the iron at first, and received some impression from the hammer. Like the others, it could not be broken while cold without extreme violence, but proved very brittle when heated red.

5. All the foregoing compositions received a good polish. The first, in keeping ten years, has suffered no sensible change; the second has some small specks of tarnish, and the third is tarnished somewhat more, but not so much as a piece of the iron itself.

6. About an ounce of a composition of one part of platina and four of iron was surrounded, in a crucible, with Reaumur's steel-making mixture, composed of eight parts of wood foot, four parts of wood ashes, four of charcoal powder, and three of common salt: the crucible was covered and closely luted, and kept in a strong red heat for twelve hours. The metal gained an increase of about one thirty-ninth of its weight, yielded to the file more easily than at first, seemed to receive no additional hardness on being ignited and quenched in water, and did not appear to have acquired:

acquired any of the qualities by which steel is distinguished from iron.

7. A piece broken off from the same ingot, weighing about three quarters of an ounce, was treated in the same manner with the powder for softening cast iron, viz. bone ash with a small mixture of charcoal powder. The metal was found increased in weight about one thirty-fourth: it was less hard to the file than at first, but harder than the part which had been cemented with the steel-making mixture.

It may be proper to observe, that cast iron is by no means a pure or simple metallic body, like those whose relations to platina have been examined in the foregoing articles. It seems generally to contain mineral sulphur, to which perhaps its brittleness is chiefly owing, and which is separated in the process by which the iron is made malleable. As platina appears incapable of contracting any union with pure sulphur, I have suspected, that while the platina and cast iron unite together, some of the sulphurous matter is thrown out and consumed, and that the degree of toughness, observed in the compounds, may proceed in part from this cause; but experiments have not yet been carried to a sufficient length to enable us to enter satisfactorily into disquisitions of this kind.

If however the cast iron should be as effectually purified by the platina, as it is even at the finery in the iron works, yet the toughness of the mixtures would still be pretty remarkable, considering how much platina, when its proportion is large, is disposed to diminish this quality in all the other metals. Perhaps platina, for certain purposes, may prove a valuable addition to this most useful metal; a metal to which the workmen cannot communicate the hardness which is often required, without communicating at the same time brittleness and intractability.

#### XIV. *Platina*

XIV. *Platina with metallic glaffes.*

Mr. MARGGRAF, after having fatisfied himself that platina perfectly refifts the common unmetallic fluxes of the vitreous and faline kind, as related in the fourth fection of this history, proceeded to try if the more active glafs of lead would ferve as a flux for it.

A glafs of lead, prepared from four parts of the fineft minium and one part of pure flint, was reduced into powder and paffed through a fine fieve, to feparate any metallic grains that might remain in it. Eight ounces of the powder were mixed with one ounce and a half, or 720 grains, of platina, and the mixture urged with a ftrong fire, in a clofe luted crucible, for two hours: a white or greyifh brittle regulus was obtained, covered with a yellowifh fcoria. The regulus was remelted with more of the fame glafs of lead, and kept again two hours in fufion: it looked as before, had a like yellow fcoria, and weighed 606 grains, or about a fixth part lefs than the platina employed. Kept in fufion two hours in a clofe crucible, it loft fix grains, or about a hundredth part. It was then beaten in pieces in an iron mortar, and mixed with an ounce of common green glafs in fine powder: the mixture being kept melted for three hours in a covered crucible, the fcoria proved turbid, inclining to greenifh, and in fome parts to bluiſh; the metal had loft thirty grains, or about a twentieth; it filed well, looked very white in the marks of the file, had ſome toughnefs, and did not very eafily break under the hammer. It was again expofed to a ftrong fire for two hours in a clofe crucible, with half an ounce of calcined borax: the borax run through the crucible, but the metal did not perfectly melt, only baking into a maſs, of an unequal rough ſurface, porous, eafy to break, in the fracture of a grey and white colour intermixed, in weight.

weight 540 grains, so that it had lost above a twentieth part more. It was further treated with half an ounce of calcined borax, the same quantity of powdered white flints, and an ounce of salt of tartar: the mixture being urged for two hours in a close crucible, with a vehement fire, the scoriae were of a topaz inclining somewhat to a chrysolith colour; the metal of a fine white colour, spongy, rough on the surface, in weight 450 grains, so that it had lost in this fusion one sixth part, and weighed now three eighths less than the platina at first.

It may be presumed, that the metal obtained in this experiment was no other than a mixture of part of the platina with some lead revived from the glafs. Though the author took care, by covering and luting the crucible, to guard against the falling in of any inflammable matter that might revive the lead, yet such a matter might have happened to be introduced in the pounding and sifting of the glafs; and independently of any accident of this kind, there was, perhaps, in the platina itself, a power sufficient for producing the effect. Common platina, such as Marggraf employed, plainly contains iron; and on barely stirring glafs of lead in fusion with an iron rod, part of the lead is revived. I mixed some of the purer grains of platina both with glafs of lead and with glafs of antimony, and exposed both mixtures to a fire as strong as I could excite: the platina shewed no disposition to melt, the grains remaining of their usual appearance. Vogel seems therefore to have ill understood Marggrafs experiments, when he concludes from them that platina yields a white regulus with glafs of lead.

Mr. Marggraf gives also another experiment of the fusion of platina, with an arsenicated glafs of lead. A glafs was prepared by melting together eight ounces of minium, two of flints, and one of white arsenic. Six ounces

ounces of this glass in fine powder were mixed with one ounce of platina, and the mixture melted in a close crucible for two hours. A brilliant regulus was obtained, greyish on the fracture, but when filed pretty white, weighing twenty-eight grains, or about one seventeenth, more than the platina: the scoria was of a dark brown colour.

Here the increase of weight is a full proof that the fusion of the platina was owing to its having imbibed either lead or arsenic from the glass: in the brilliancy of the surface, and the grey colour of the internal part, Mr. Marggrafs metal agreed with our masses of arsenicated platina already described; and probably the using of arsenic in a state of vitrification with substances which serve to detain it in the fire, may be the most effectual means of combining this volatile metallic body with platina.

XV. *General observations on the mixtures of platina with other metals.*

1. IT appears from the foregoing experiments, that platina, unfusible by itself in the strongest fires of our furnaces, and proof against the most active unmetallic fluxes, melts with, or is dissolved by, every one of the common metallic bodies: That the different metals dissolve it with different degrees of force, and this not in proportion to the degree of their own fusibility: That there are remarkable differences in its relation to different metals, in regard to the change which it produces in the quality of the metal; that it hardens, and diminishes the malleability of, all the malleable metals, but seems to communicate some degree of toughness to one which of itself has none, viz. cast iron; that it diminishes the malleability of tin more, and of gold less, than of the other metals; that in certain quantities, it debases the colour of all the metals, communicating to

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some its own whiteness, as to copper, and producing with others a new colour, as with bismuth, lead, and gold; that it preserves copper and iron from tarnishing or rusting in the air, but occasions lead and bismuth to tarnish in a remarkable manner.

2. Though platina, when its quantity is not very large, becomes fluid with most of the metals in a moderate fire, a strong one seems to be always requisite for its perfect and total solution. Compositions of copper, of silver, and of lead, with one third their weight of platina, which had flowed thin enough to run freely into the mould, and appeared to the eye perfectly mixed; on being digested in aquafortis till the menstruum ceased to act, left several small grains of platina in their original form. Upon viewing these with a microscope, some appeared to have suffered no alteration: others shewed a multitude of small, bright, globular protuberances, as if they had just begun to melt.

3. Mixtures of copper, silver, and lead with smaller proportions of platina, which had been kept in strong fusion for some hours that the platina might be wholly incorporated, were digested and boiled in fresh portions of aquafortis, till the platina was left by itself in fine powder, free from any thing that aquafortis could extract. These powders were exposed to very vehement fires, without addition, with the addition of borax, with alkaline salts, and with flint glass: they proved as unfusible as the platina at first, neither melting, nor communicating any colour to the salts or glass. It appears therefore that the platina is only simply dissolved by the metals in fusion, and does not by their means become truly fusible itself.

4. As platina unites with several metals into compounds of new qualities, such as the ingredients neither possess separately, nor can be conceived, on any known mechanical

nical principles, to produce by their simple junction; and as such new properties seem to be in no metallic mixture more conspicuous than in those which platina affords; it follows, that the dissolution of platina by metals is by no means a superficial mixture, but as perfect and intimate a coalition as we have grounds to believe that of any one metal to be with any other.

## S E C T. VI.

*Of the specific gravities of mixtures of platina with different metals.*

**A**MONG the experiments communicated to the Royal Society by Mr. Wood, there is a remarkable one of the specific gravity of a mixture of equal parts of platina and gold. The gravity of the heaviest platina he examined was to that of water as 15 to 1; and the gravity of gold, as we have seen in the history of that metal, is about  $19\frac{3}{4}$ . If 15,0 parts of platina lose one on being immersed in water, and 19,3 parts of gold lose 1; then, if the two metals be mixed in equal quantities, 34,3 parts of the compound should lose 2; whence, dividing 34,3 by 2, we have 17,150 for the gravity of the compound. Such ought the gravity to be, if the two metals were joined superficially, and each preserved its own proper volume; but when melted together, the specific weight of the mass is said to have been considerably greater, amounting to no less than 19. If this be the case, 19 parts of the melted mass must occupy no more space than  $17\frac{1}{6}$  did before the fusion; so that near a fourth part of one metal is received into the pores of the other, without increasing the bulk of the mass. It may be suspected, that the substance which Mr. Wood weighed by itself under the name of platina was the lighter cast metal mentioned at the begin-

ing of this history, and that what he melted with gold was the true platina; in which case, the gravity of platina being supposed 17, the increase of gravity on mixture comes out about a twentieth part, so that about a tenth part of the platina has its bulk lost in the mass.

To satisfy myself in this point, I weighed hydrostatically the mixture, already mentioned, of equal parts of platina and gold. The specific gravity of the gold was 19,285: the platina was the larger grains, whose gravity, as we have seen in the first section, was at least 17. The compound weighed in air 13605, and lost in water 750, whence its gravity was 18,140: the gravity by calculation comes out 18,071; so that though the platina's gravity had been no more than 17, the increase of gravity from the mixture was not very considerable. As a little loss had happened in the fusion of this mixture, and as the specific weight of the platina employed was not certainly known, I made two fresh ones, with pieces cut off from the same mass of gold, and some of the largest grains of platina, whose gravity was nearly 18. One of these mixtures, weighing 5129, lost in water 276; and the other, weighing 6415, lost 345; whence the specific gravity of the former turns out 18,583, and that of the latter 18,594, which come as near to one another as can well be expected in experiments of this kind: the gravity by calculation is 18,622; so that both mixtures were a little specifically lighter, or expanded into a larger volume, than if the metals had been weighed separately, or joined by simple apposition of parts. As these experiments were made with a good deal of care, it may be presumed that in those, where there seemed to be a great increase of gravity, or contraction of volume, either some error happened in the weighing, or the platina had not been all taken up by the gold in the fusion.

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I weighed also hydrostatically the other mixtures of platina and gold, and sundry mixtures of it with different proportions of the other metals. Such masses as could bear the hammer, were gently hammered a little, with care not to make them crack; for the pure metals themselves, after fusion, are seldom found to come up to their true specific weight, till brought to greater solidity under the hammer. The surface was filed smooth, where any cavities or irregularities were likely to retain air; and most of them were kept immersed in water for an hour or more, that the air might be more effectually extricated, and the water more closely applied to them. The effect of this precaution was manifest in some trials purposely made: when the metal, hanging in water from the end of the beam, had been cleared from all visible air bubbles, and exactly counterpoised; on standing for an hour or two, it sensibly, and sometimes very considerably preponderated. The water was in some of the trials melted snow, and in others distilled water, which were both found to be of the same specific weight. The temperature of the air was from the 50th to the 60th degree of Fahrenheits thermometer.

The balance, made use of in these experiments, was of great sensibility, but not exactly equibrachial: and here it may be proper to observe, that though the writers on balances require, and are very solicitous about procuring, a perfect equality of the arms; yet as this equality is exceeding difficult, if not impossible, to be obtained, so neither does it appear anywise necessary to the accuracy of the instrument. If ten equal small weights, put into one scale, are counterpoised by a weight in the other; and if the ten weights be then removed, and a bit of silver or brass plate put in their room; it is evident, that when this plate shall be made equiponderant to the counterpoise, it will

will be exactly equal in weight to the ten, how unequal soever the arms of the balance may be ; and consequently, that any unequal-armed balance may, on this principle, have a set of weights adjusted to it, which being used always in one scale, the instrument shall be of the same accuracy as if the arms were most exactly equal. The best way of procuring equal small weights is, by cutting off equal lengths of the finest silver wire : the silver thread, kept equally stretched by a heavy body at the end, may be coiled close round a thicker piece of brass wire, and all the coils cut through at once by a sharp instrument applied lengthwise. Silver wire is drawn to such fineness, and of so uniform thickness, that weights, thus made by mensuration, are of greater nicety than it is possible for any balance to weigh. A piece of the wire, whose length is very sensible and much further divisible, shall not have weight enough to give any sensible motion to the tenderest balance. These small pieces, or such as will but just move the balance when empty, and which consequently will not move it at all when loaded, I have found to be a very useful appendage to the adjusted series of weights. Though a balance appears exactly in equilibrio, yet one side may really preponderate, by any quantity of force, less than that which is sufficient to overcome the friction on the center : as less additional force will serve to depress this side than the other, one of the small weights, tried first in one and then in the other scale, will enable us to judge whether the equipoise is exact, or on which side the preponderation lies.

The results of these experiments were published in the Philosophical Transactions, together with the gravities of the several mixtures deduced from calculation ; from which it appeared that the experimental gravities were almost always less than the computed. But an error in  
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those calculations has made the computed gravities in general too great: for though the ingredients in each mixture were proportioned to one another by weight, the calculations were inadvertently made as if they had been taken by volume. The discovery of this mistake I owe to Mr. Scheffer, who gives a paper on this subject in the Swedish transactions for the year 1757.

The computed gravities being rectified, there appears to obtain, in several of the mixtures, some degree of what the above experiments shew not to obtain in those with an equal quantity of gold; the compounds being of greater gravity, or more contracted in volume, than the two metals considered separately.

This excess of the experimental gravities above the computed is attributed by Mr. Scheffer to the gravity of the platina being greater than that which I had assigned to it. He imagines, that particles of air, adhering in the cavities of the rugged grains, had occasioned them, when weighed in water, to occupy a larger space than that of their own proper bulk; and that, when the platina was melted into a mass with other metals, it then discovered its true gravity. On this foundation he endeavours to deduce, from the specific weights of the mixtures, that of the platina itself; one of the most important points, as he observes, in its philosophic history, that I had left undiscovered. Though I failed, on account of the above inadvertence, of attaining to its true weight, my experiments, he thinks, lead to it; and from those experiments he concludes, that it is certainly more ponderous than pure gold.

This point seems to require some further examination: for such a conclusion is not to be received without the strongest proofs; and if the principle of induction is not perfectly just, it may give rise to fallacies of worse consequence than an error in the gravity of platina.

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I have therefore computed the gravities anew, together with the gravity which each mixture gives for the platina. The first column, in each of the following tables, contains the proportions of the two metals in the several mixtures, the loss sustained in fusion, where there was any, being deducted: as platina itself suffers no diminution in the fire, it is from the quantity of destructible metal mixed with it that this deduction is made. The second column contains the specific gravities of the mixtures as found by experiment, and the third their gravities by calculation supposing the platina's gravity to be 17: in the fourth is shewn the difference between the experimental and computed gravities, with the marks + or -- according as the former is greater or less than the latter. The last column gives the gravity of platina deduced on Mr. Scheffers principle from each of the mixtures.

G O L D		Specific Gravity			Platina's Gravity resulting
		By Exper	By Calcul.	Difference	
		19,285			
Platina 1,	Gold 2 - -	18,378	18,458	,080 --	16,797
Platina 1,	Gold 3 - -	18,613	18,658	,035 --	16,852
Platina 1,	Gold 5 - -	18,812	18,862	,050 --	16,759
Platina 1,	Gold 11 - -	18,835	19,071	,236 --	14,988
Platina 1,	Gold 15 - -	18,918	19,124	,206 --	14,723
Platina 1,	Gold 23 - -	19,089	19,177	,188 --	15,481
Platina 1,	Gold 31 - -	19,128	19,204	,076 --	15,273
Platina 1,	Gold 47 - -	19,262	19,231	,031 +	18,711
Platina 1,	Gold 95 - -	19,273	19,258	,015 +	18,214

As the experiments with gold had not come to Mr. Scheffers hands when he wrote his paper, he was in hopes, that when such experiments should be made, they would give platina's gravity with certainty; gold being free

free from some of the causes of error which attend the ether metals. It appears however from the foregoing account, that of twelve mixtures of platina and gold, there was not one so heavy as the gold itself, whereas on Mr. Scheffers principle they ought all to have been heavier. It is plain therefore that either platina is not so heavy as gold, or that the principle of induction does not obtain in the mixtures of gold and platina.

From the two last mixtures, the gravity of platina comes out between 18 and 19; but on these no dependence can be had, the difference between the experimental and computed gravities being so inconsiderable, that it may be attributed to the unavoidable imperfections of the instruments used for the weighing; for an error of less than a thirty-thousandth part of the weight makes a difference of ,012 in the specific gravity of the mixture, and of 1,000 in that of the platina deduced from it. The case is the same in the mixtures with other metals where the platina is in small proportion.

The other compositions give the platinas gravity less than 17; and as the platina is found by itself to be 17 or more, it seems to follow, that there must necessarily be a diminution of gravity produced by the union of the two metals with one another. A phenomenon observed in the fusion appeared to confirm this. Most metallic bodies, made fluid by fire, shrink and assume a concave surface in their return to solidity: pure gold shrinks perhaps rather more than any of the others. But mixtures of gold and platina, where the platina was in considerable proportion, were observed to shrink little; some of them even expanded and became convex. Of this expansion or dilatation of volume, a decrease of specific gravity is the necessary consequence.

As the purest grains of crude platina have some admixture of heterogeneous matter, it is possible that this matter may prevent the intimate union of the platina and gold, and thus occasion the two metals, when blended together, to occupy a larger volume than naturally belongs to them. I therefore melted gold with platina that had passed through some of the operations hereafter described, and which may be presumed to have been thereby purified from most of its heterogeneous parts.

One of the neatest beads of platina cupelled with lead, (article vi. No. 5, of the following section) was melted with equal its weight of gold in a strong fire, and continued in fusion about an hour: the mass proved spongy and very light. I remelted it several times, with the most vehement fires I could excite; and in order to separate as much as possible of the lead, to which its sponginess seemed owing, I beat it in pieces, and boiled it in aquafortis, and repeatedly injected corrosive sublimate upon it during the fusion. The mass nevertheless still turned out cavernous, and brittle, and specifically lighter than either the gold or the bead of platina were by themselves.

Platina dissolved in aqua regia was precipitated by mercury, and the precipitate boiled in aquafortis and well washed with hot water. Twenty-six grains of this preparation were melted with four times as much gold: the platina seeming to be imperfectly mixed, the fusion was three or four times repeated, and the quantity of gold increased to about eight times that of the platina. This mixture proved as ponderous as the gold itself, or rather more so: it weighed in air 16802, and in water 15934, whence its gravity was 19.357. It was examined by some other gentlemen as well as myself, who all agreed in its being remarkably heavy: Dr. Pemberton, with a very exact balance, found the weight in air 229.735 grains, and  
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in water 217.885, from which numbers the specific gravity comes out 19.387.

LEAD	Specific Gravity			Platina's Gravity resulting
	By Exper.	By Calcul.	Difference	
	11,386			
Platina 1, Lead 0,97	14,029	13,679	,350 +	18,105
Platina 1, Lead 1,92	12,925	12,838	,087 +	17,459
Platina 1, Lead 3,97	12,404	12,196	,308 +	19,242
Platina 1, Lead 8 -	11,947	11,819	,128 +	19,732
Platina 1, Lead 12 -	11,774	11,682	,092 +	19,923
Platina 1, Lead 24 -	11,575	11,538	,037 +	19,238

From this table it appears that the gravity of lead is affected by crude platina in a different manner from that of gold; the mixtures with gold being such, as if the crude grains were of less gravity than 17, but those with lead as if they were of greater; so that in one or the other case, or in both, an alteration of volume must necessarily be produced by the action of the two metals on one another.

SILVER	Specific Gravity		
	By Exper.	By Calcul.	Difference
	10,980		
Platina 1, Silver 1 - -	13,535	13,342	,193 +
Platina 1, Silver 2 - -	12,452	12,449	,003 +
Platina 1, Silver 3 - -	11,790	12,046	,256 --
Platina 1, Silver 7 - -	10,867	11,488	,621 --

Here we see the effects of the ebullition and dispersion of the silver taken notice of in the history of the fusion of platina with this metal. The last mixture is lighter even than silver itself, a proof that the metal is rarefied or made cavernulous by the action of the platina: the greater gravity of the two first mixtures was probably owing to a part of the silver having been thrown off in the fusion, and the

platina not perfectly dissolved by the rest. I took all possible precautions for preparing a set of mixtures of these two metals on purpose for this examination, but they always spluttered up so much about the crucible, that no dependence could be had upon the proportions of the two in the remaining mass.

C O P P E R:	Specific Gravity		Difference	Platinas Gravity resulting
	By Exper.	By Calcul.		
	8,830			
Platina 1, Copper 0,969	11,400	11,869	,469 --	
Platina 1, Copper 2 - -	10,410	10,514	,104 --	
Platina 1, Copper 4 - -	9,908	9,768	,140 +	19,364
Platina 1, Copper 5 - -	9,693	9,598	,095 +	18,970
Platina 1, Copper 8 - -	9,300	9,328	,028 --	
Platina 1, Copper 12 - -	9,251	9,168	,083 +	21,607
Platina 1, Copper 25 - -	8,970	8,996	,026 --	

Mr. Scheffer remarks that copper of itself can never be cast close; that when melted with a weak heat, it proves so incompact as not to bear the hammer; and that when melted in a strong heat, with the addition of inflammable matter, in order to render it malleable, it proves cavernulous on the outside. The irregularity in the above set of experiments seems to shew that something of the same kind happens in the mixtures of copper and platina; since four mixtures out of the seven were lighter than they ought to have been, and this not from any uniform action of the two metals on one another, but apparently from accidental porosity. I melted some of the mixtures a second time, and found their gravities considerably altered: that of 11,400 was increased to 11,693; and that of 9,251 was diminished to 8,985. Little therefore can be concluded from these mixtures, in regard either to the gravity of the platina, or its effect in varying the gravity of copper.

I R O N.



I R O N	Specific Gravity		Difference	Platinas Gravity resulting
	By Exp.	By Calc.		
	7,100			
Platina 1, Iron 1,295	9,917	9,511	,406 +	20,403
Platina 1, Iron 3,333	8,700	8,202	,498 +	34,963
Platina 1, Iron 5,150	8,202	7,842	,360 +	40,951
Platina 1, Iron 10 - -	7,862	7,496	,366 +	
Platina 1, Iron 12 - -	7,800	7,432	,368 +	

The compositions with silver have afforded a proof of the diminution of gravity from mixture, or of the mass being dilated, from the action of the ingredients upon one another, into a larger volume than they occupied separately. The above compositions with iron seem to be as striking instances of a contrary effect: the gravity of the two last of them is such, as no substance, however ponderous, could possibly produce by the simple apposition of its own parts to those of the iron; for it appears in the calculation, that the platina and iron together occupy less volume than even the iron by itself.

Mr. Scheffer very ingeniously accounts for this remarkable phenomenon from a singular property of iron. When metals are deprived by calcination of their phlogiston or inflammable principle, their absolute weight is increased: iron, by complete calcination, receives an augmentation of one third of its weight. Cast iron has this particularity, that it can bear a considerable dissipation of its phlogiston, without calcining, or without losing its metallic form; and in proportion to this dissipation its absolute weight is increased. Now, as the above ponderous mixtures were melted without any inflammable addition, he thinks a part of the phlogiston of the iron must necessarily have been burnt out in the fusion, and the metal of consequence acquired an additional weight; but that, as no increase was observed;

observed on weighing it, a part of the iron, equal to the acquired weight, must have been scorified and lost, and consequently the volume of the metal diminished; so that there remained with the platina as great a weight of iron as at first under a less volume.

To satisfy myself whether the increase of specific gravity, or diminution of volume, was owing wholly to this cause, I made another mixture. But as cast iron is a very impure metal, I took a piece of a bar of the best forged iron, and cemented it with a mixture of wood foot and powdered charcoal, till it had imbibed so much of the inflammable matter as to become steel; repeating the cementation, with a fresh mixture, till the steel melted. The metal in this state was very brittle, so as without much difficulty to be reduced into powder. A portion of this powder was mixed with charcoal powder, and melted again: 7000 grains of the steel powder, and 1000 grains of platina, were likewise mixed with charcoal powder and melted in a close crucible. The specific gravity of the forged iron was 7,795; which by the introduction of phlogiston in the first cementation was diminished to 7,618. By the repeated cementation and fusion, the gravity was diminished to very little more than 7. Of the powdered steel melted with the charcoal powder, the gravity was 7,032, very nearly the same as before this last fusion. Of the powdered steel and platina melted with charcoal powder, the gravity was 7,760, which still exceeds the computed gravity, though not in so great a degree as that of the mixtures with as large proportions of cast iron. The melted mixture weighed 30 grains less than the two ingredients before the fusion, on account, perhaps, of some small grains of the metal remaining dispersed among the charcoal powder. Though this loss be supposed to have been of the steel only, yet, as there will remain

main 697 parts of steel with 100 of platina, and as 7,76 parts of the mixt lose 1 in water, the gravity of the platina comes out on calculation no less than 27,813.

It appears therefore that iron is very variable in its specific weight, in the different circumstances of being melted or forged, and impregnated more or less with phlogiston; but that probably some other cause also concurs in varying the gravity of mixtures of it with platina. This cause may perhaps be found in a remarkable property of iron, which the experiments related in the former part of this work (page 261) seem to have established. Melted iron, in the instant of its becoming solid, is dilated into a larger volume, and one of the marks of this dilatation is the convexity of its surface in circumstances wherein that of other metals is depressed. Platina seems to destroy this power in iron. In the first mixture I made of cast iron and platina, the surface was as much hollowed as that of any metallic mass I remember to have seen, nor was this phenomenon omitted in the account of the experiments printed in the Transactions. If then fluid iron expands in fixing, and the admixture of platina occasions it to contract, or to expand less, we need not wonder at the increase of gravity in the hydrostatical experiments.

T I N	Specific Gravity			Platinas Gravity resulting
	By Exper.	By Calcul.	Difference	
	7,180			
Platina 1, Tin 0,984	10,827	10,129	,698 +	21,649
Platina 1, Tin 1,966	8,972	8,920	,052 +	17,619
Platina 1, Tin 4 - -	7,794	8,117	,323 --	
Platina 1, Tin 8 - -	7,705	7,672	,033 +	18,613
Platina 1, Tin 12 - -	7,613	7,513	,100 +	26,745
Platina 1, Tin 24 - -	7,471	7,349	,122 +	27,368

The

The first of these mixtures with tin is that from which Mr. Scheffer endeavours to obtain the true gravity of platina, and from this it comes out 21,649. He observes that tin is not variable, as iron is, in its gravity, or quantity of phlogiston, so long as it preserves its metallic form; and hence concludes, that when platina and tin are melted together, the excess of the specific weight of the mixture above that of the tin, must give the true specific weight of the platina. As the experiment on equal parts of tin and platina, makes the gravity of platina, on this principle, above 21, he seems to think that all the mixtures, whose gravity was found such as to make platinas gravity less than this, must have been porous, and are therefore to be disregarded in the present enquiry. He remarks, from the whole, that though the specific weights of fluids may be determined accurately enough by hydrostatical experiments, we cannot be so certain about that of solids, on account of cavities, incompleteness, and air bubbles adhering; that the experiments on the foregoing mixtures afford a proof of this, mixtures of platina with one and the same metal being sometimes heavier, and sometimes lighter, than they ought to be by calculation; and that the same thing happens also in the pure unmixed metals, according as they are cast in a weaker or stronger heat.

The gravities of metals are doubtless influenced not a little by circumstances of this kind; and it must be added, that in the mixtures with platina, there is another cause of variation, which has not yet been attended to. When platina is melted with other metals in any considerable proportion, a part of the platina, unless the mixture is cooled hastily, is apt to separate before the fluid sets, so that unless the whole mass be weighed in the hydrostatic balance, which was not the case in some of the foregoing experiments, we cannot be sure but the part weighed may  
have

have more or less than its due proportion of platina. In the mixtures with some metals, as lead, this unequal distribution, or separation of the platina, is very visible; and it may be presumed to happen in a greater or less degree in the mixtures with all the metals, though it cannot always be distinguished by the eye. Compositions of platina with zinc, tin, and copper, by all which the platina seems to be uniformly enough dissolved, were poured into narrow cylindrical moulds: the cylinders being broken in two, the lower half of each was found to be of considerably greater gravity than the upper.

Thus much however the experiments demonstrate, that in some instances, in the mixtures with silver at least, there is a true diminution of gravity, from the action of the ingredients upon one another: and if they do not demonstrate, they render it extremely probable, that in some cases, particularly in the mixtures with iron, there is a true increase of gravity. If an increase or diminution happen in the mixtures with one metal, we cannot be certain but they may happen also in those with another; and consequently the specific gravity of platina cannot be inferred with certainty, or even with probability, from that of any mixture of it with any metal.

Of a variation of gravity produced by mixture, there are some remarkable instances in the other metals also. Copper, whose specific gravity was 8,830, was melted with half its weight of tin whose gravity was 7,180: there was a little loss in the fusion, which we need not here regard, for the mixture was specifically heavier than the heaviest of the metals by itself, its gravity being 8,898: both the mixture, and a piece of the copper, were examined by some other gentlemen, who all reported the mixture to be the heaviest, although, as is usual in trials of this kind, there were some differences in the numbers: if, from the

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gravity

gravity of this mixture, we were to compute that of the tin employed in it, we should make it above a fourth part greater than it really is.

Mr. Hooke made an experiment of the same kind, before the Royal Society, on a mixture of tin and silver. The gravity of the tin was about 7, and that of the silver 10,666: of equal parts of the two metals melted together, the gravity was 10,812. By applying Mr. Scheffers principle to this mixture, if silver was a metal of unknown gravity, we should conclude, that its gravity must be upwards of 23. Several other experiments of the gravities of metallic mixtures are given in Dr. Birch's history of the Royal Society; but the reader must observe, that the computed gravities are no where to be relied on, Mr. Hooke having fallen into the same mistake, in regard to the calculations, as I had done in the tables published in the Philosophical Transactions.

Dr. Brandt, in the Swedish acts for 1744, where we likewise find an inadvertence of the same kind in the method of calculation, gives three experiments on mixtures of lead and tin; in two of which there is such an increase of gravity, as would make the specific weight of lead above 13, and in the third a more remarkable one: 531 grains of fine tin lost in water  $75\frac{1}{2}$ , so that 100 parts lost 14,218: 531 grains of a mixture of 87 parts fine tin and 3 parts lead, lost in water  $72\frac{1}{2}$ , so that 100 parts of this mixture lost 13,653: the quantity of tin in it ought to have lost more, or to have occupied a greater space in the water, than the whole mixt did; so that the lead and tin, by their mixture, were contracted into less volume than that of the tin by itself.

It appears therefore that the gravity of a metal can never be with any certainty deduced from that of its mixture with another metal, as a dilatation or contraction of the volume may result from their action on one another. It follows.

follows also, that when two metals of known gravities are melted together, their proportions cannot be found from the gravity of the compound, without a previous hydrostatic examination of known mixtures of them in different proportions; that consequently the celebrated proposition of Archimedes is of more limited use than it has generally been supposed; and that the table which Mr. Scheffer has been at the pains to calculate, in the Swedish acts for 1755, for determining the quantities of lead and tin in any given mixtures of the two, by a statical examination of them, without comparison with standard mixtures, is little to be depended on.

As the variations of gravity arising from the mixture of metals have been ascribed to causes which do not obtain in fluids; it may be proper to observe, that the same thing often happens in fluids themselves; and here the effect is perhaps still more conspicuous and more strongly marked. One measure of water, and one measure of rectified spirit of wine, mixed together, fall very sensibly short of two measures; a proof that their volume is diminished, or their weight, under an equal volume, increased by the mixture. Mr. Hooke found, that twenty-one measures of water, and three measures of oil of vitriol, mixed together, made only twenty-three measures, so that one twenty-fourth part of the bulk was lost.

## S E C T. VII.

*Of the effect of fire and air on mixtures of platina with certain metals.*

### I. *Calcination of Tin with platina.*

**A**S gold and tin, melted together, and kept in a heat sufficient for calcining the tin, are said by Dr. Brandt, in the Swedish transactions, to affect one another in a

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pretty

pretty remarkable manner; the gold to become dissoluble in the pure marine acid, which gold by itself resists; and the tin to become easily vitrescible, though otherwise it can scarce be vitrified at all; I treated platina and tin in the same manner.

Two parts of the picked grains of platina and three parts of tin were melted together, the mixture reduced into powder in a clean iron mortar, and a hundred and sixty grains of the powder set in a cupel, under a muffle, in such a heat as is employed for the cupellation of silver. The cupel being taken out, the matter appeared of a dark purplish colour, and part of it stuck together into a lump. It was then put into an unglazed porcelain saucer, set again under the muffle, and stirred every now and then for two hours: here and there some grains appeared glowing, like bits of burning coal; a phenomenon which tin usually exhibits in its calcination. The powder, when cold, looked of a mixed greyish-reddish colour, the red prevailing: it weighed thirteen grains more than at first, so that it had gained an increase of about one twelfth, exclusive of part of it which had stuck both to the cupel and to the roughish surface of the unglazed saucer.

A part of the calx was urged in a covered crucible, with a strong fire in a blast furnace, above an hour. It did not in the least melt, and baked together but very slightly: its colour was darkened almost to a black. Both the red and the black calces, digested in spirit of salt, gave pretty deep yellow tinctures, like diluted solutions of platina in aqua regia; whereas neither the grains of platina, nor the tin calcined by itself, give any colour to the acid.

## II. *Separation of Mercury from platina.*

SOME quicksilver, which by long trituration with platina had dissolved a part of the metal, was put into an iron  
ladle,



ladle, and exposed to a moderate fire. The mercury evaporated freely, and left the platina behind, in form of a dark coloured powder intermingled with some small bright shining particles. It may be presumed that the platina, by this dissolution in quicksilver, is purified from great part of its iron, a metal which quicksilver has little disposition to unite with.

### III. *Separation of Arsenic from platina.*

PIECES of platina, which had been melted with arsenic, were urged with a very strong fire in an open crucible. Arsenical fumes, distinguishable by their garlic smell, arose in abundance for some time: at length the fumes entirely ceased, and the platina remained in a spongy mass. On this mass I injected a fresh quantity of arsenic, so as to bring it into fusion, and having then hastily excited the fire till the fumes ceased, found the matter again spongy, and nearly of the same weight as after the first operation. This was repeated three or four times, with the same event. It did not appear that the arsenic carried off with it any part of the platina, as it does of all the other metals, gold itself not excepted: but a portion of the arsenic seemed to be retained by the platina even in strong fires. Though the mass was pretty compact when so far satiated with the arsenic as to be in some measure fusible, it always became spongy when so much of the arsenic had been dissipated as to leave the platina unfusible. All these masses were specifically lighter than the platina at first, the gravity of the heaviest of them being only about 16,800.

### IV. *Separation of Regulus of antimony from platina.*

A MIXTURE of platina and regulus of antimony was melted in a strong fire, in a shallow wide crucible, and the use of a bellows directed obliquely upon the surface of the fluid.

fluid. The matter continued to flow, and to fume copiously, for some hours : at length it became consistent in an intense white heat, and scarcely emitted any more fumes though strongly blown on. The mass, when grown cold, broke easily, appeared very porous, blebby, of a dull grey colour, and weighed considerably more than the quantity of platina employed. Its specific gravity was only about 15.

This experiment was several times repeated, and the event was always the same ; the platina not only resisting, as gold does, the volatilizing power of the antimonial regulus, but likewise defending a part of it from the action of the fire and air, and refusing to melt after a certain quantity had been dissipated.

I likewise treated platina with crude antimony. Four ounces of antimony and two ounces of platina, kept for some time in a fire pretty strongly excited by bellows, appeared melted only in part : four ounces more of antimony being added, and the fire renewed, a reguline matter was found partly at the bottom and sides of the crucible, and partly intermingled among black spongy scoriæ : the whole was returned to the fire with black flux and common salt : it now melted sufficiently thin, and the regulus perfectly separated. This regulus did not differ in appearance from mixtures of regulus of antimony and platina melted together, and exhibited the same phenomena also on trying to blow off the antimonial part.

Mr. Scheffer likewise tried platina with antimony, and the result of his experiments was the same as of mine. He observes that as platina resists sulphur equally with gold, it cannot be scorified by the sulphureous part of antimony, and therefore remains, as gold does, in the regulus ; but that the regulus cannot be blown entirely off from it, as it is from gold, on account of the platina not continuing fluid.

V. *Separation of Zinc from platina.*

A MIXTURE of platina and zinc, exposed hastily to a strong fire, deflagrated and appeared in violent agitation. This continued but a little time: the matter quickly became solid, and could no longer be made to flow, or the zinc, of which a considerable quantity still remained in it, to flame. The mass was very brittle, dull coloured, spongy, and, like the two foregoing, specifically lighter than the crude platina.

VI. *Cupellation of platina with Lead.*

1. A MIXTURE of platina and lead was cupelled under a muffle in an assay furnace. For some time the process went on well; the lead smoking moderately, and changing into scoriæ, which were thrown off to the sides and absorbed by the cupel. In proportion as the lead worked off, the matter required a stronger fire to keep it fluid; and at length, collecting itself into a dull flat lump, it could no longer be made to flow in the greatest degree of heat which the furnace was capable of giving. The lump broke easily under the hammer, appeared of a dull grey colour both internally and externally, and of a porous texture. It weighed near one fifth part more than the quantity of platina employed.

2. This experiment was many times repeated and varied. I endeavoured to scorify the lead in assay crucibles, by intense fires in a blast furnace; to work it off on bone-ash pressed into the bottoms of crucibles; and to blow it off on tests before the nose of a bellows. The event was still the same; the platina not only resisting the power of lead, which in these operations destroys or scorifies every other known metallic body except gold and silver, but likewise retaining, and preventing the scorification of, a part of the lead itself.

3. In the history of the fusion of platina with lead it has been observed, that lead deposites, in a gentle heat, great part of the platina which had been united with it in a strong one. As the part which remains suspended in the lead, might be suspected to differ from that which subsides, a quantity of lead was decanted from fresh parcels of platina in a heat below ignition, and both the decanted metal and the residuums submitted to cupellation separately. The event was the same in all; the metal becoming consistent after the lead had been worked off to a certain point, and refusing further scorification.

4. Mixtures of platina and lead, which had been cupelled in an assay furnace as long as they could be kept fluid, were exposed to stronger fires in a blast furnace, by themselves, with powdered charcoal, with black flux, with borax, with nitre, and with common salt. None of them perfectly melted, or suffered any considerable alteration; they only became somewhat more porous, probably from the exudation of some of the lead and a partial liquefaction or softening of the mass. The immediate contact of burning fuel, agitated by bellows, made some of these mixtures flow after they had refused to melt in crucibles acted on by intense fires: the beads by this means became somewhat neater and more compact, but very little of the lead was separated.

5. The cupelled beads were in general brittle, breaking easily under the hammer, without stretching in any considerable degree. They were of a grey colour both on the upper surface and in the fracture, but pretty bright and white on the lower surface, and when ground or filed: they had nothing of the purplish hue, which the mixtures of platina and lead (page 515) had in so remarkable a degree; nor does their colour appear anywise altered after keeping for ten years in the same circumstances in which those

those mixtures were kept. On weighing them hydrostatically, the more spongy ones were found nearly as ponderous as the crude platina. Among the more compact, the gravity of one turned out 19,083, that of another 19,136, and of a third 19,240. It is probable that these remarkable gravities proceeded partly from the platina having been purified in the process from its lighter heterogeneous admixtures, and partly from an increase of gravity occasioned by the coalition of the platina with the lead. The last of these mixtures, whose gravity was 19,240, is that which was melted with equal its weight of gold, as mentioned in page 548.

6. A mixture of one part of platina and three of gold was cupelled with lead in an assay furnace. The matter worked well for a considerable time: at length it collected itself into a bright hemispherical lump, which by degrees became flatter, dull coloured, and rough. The button, on being weighed, was found to retain about a twelfth part of lead.

7. The experiment being repeated with a mixture of one part of platina and six of gold, some part of the lead appeared still to be retained. The bead proved rounder and brighter than the foregoing, and of a good golden colour on the outside; but it broke easily under the hammer, and appeared internally greyish: some of the fragments hung together by the outward golden coat.

8. Mixtures of platina and silver, submitted to the common process of cupellation, retained likewise a little of the lead. These, in becoming consistent, formed not hemispherical beads, but flat masses, very rough and brittle, and of a dull grey colour both externally and internally.

9. The cupellation of platina with lead was one of the experiments made by Mr. Wood, and communicated to the Royal Society in the year 1750; but the platina being

then very imperfectly known, some deception happened in this point. Mr. Wood relates, that platina having been melted in an assay furnace on a test with lead, and therewith exposed to a great fire for three hours, till all the lead was wrought off, the platina was afterwards found remaining at the bottom of the test, without having suffered any alteration or diminution by this operation. Dr. Brownrigg, surprized at this resistance of platina to lead, repeated the experiment. He melted twenty-six grains of platina upon a cupel, with sixteen times its weight of pure lead, which he had himself revived from litharge: the lead being scorified, there remained in the cupel a button of platina weighing twenty-one grains, so that the platina lost in this operation near a fifth part of its weight. From this experiment he conjectured, and not without probability considering the little that was then known of the properties of this new metal, that a part of the platina was scorified by the lead; that the whole might have been scorified by repetitions of the process; and that consequently gold and silver may be purified from platina, by cupellation with larger quantities of lead than are commonly employed. What the author has modestly proposed only as a conjecture, to be confirmed or refuted by further trials, has by some been taken for a certainty: in a letter presented to the Royal Society soon after, the process is spoken of as a method discovered by Dr. Brownrigg, for separating platina from gold and silver. It is plain that this experiment must have been made, and the author has lately informed me that it was, with the cast metal mentioned at the beginning of this history, which was then supposed to be true platina, and does lose of its weight in the common process of cupellation.

10. Mr. Scheffer tried the cupellation of the grains of platina with lead, and the event was exactly the same as in  
my

my experiments. The bead was dark coloured and rugged at top, white underneath, and retained a portion of the lead amounting to two or three parts in a hundred. He observes that the lead cannot, by common fire, be worked off clean from this metal, as it is from gold and silver, on account of the platina not continuing fluid after the lead has been separated to a certain point; and judges that a sufficient heat for the complete separation of the two metals is not to be obtained by any other means than by large burning glasses.

11. I have already observed, page 494, that platina divided by cementation with nitre, and afterwards purified by repeated sublimations of sal ammoniac, appeared no-wise different in cupellation from the common grains. Mr. Marggraf made trial of platina attenuated by solution and precipitation. The orange coloured precipitate thrown down by fixt alcali from solution of platina in aqua regia, being well washed with hot water and ignited under a muffle, became brownish: nine parts of this matter were melted with an ounce of pure granulated lead, and the mixture exposed to the fire in a scorifying dish till a considerable part of the lead was scorified: the remainder worked in a cupel, left a rough bead, of a whitish grey colour, very brittle, perfectly like that obtained in the cupellation of crude platina: its weight was one grain. The experiment was repeated with a precipitate made with volatile alcali, and the event was the same. He tried also the powder which remained on distilling a solution of platina to dryness: this powder, calcined under a muffle, acquired a shining blackish colour, in which state thirty grains of it were mixed with twenty times as much granulated lead, and the mixture worked as above, first on a scorifying dish and afterwards in a cupel: the scorixæ were of a black-brown colour: the cupelled bead was brittle and of

a grey-white colour like the others, and weighed forty-two grains, or two fifths more than the platina employed. This was treated in the same manner with the same quantity of fresh lead: the scoriæ were of the same colour, and the bead still weighed just forty-two grains.

12. The same author gives an account of another operation, in which platina and silver were combined together, the mixture melted with lead, the lead scorified, the silver separated by aquafortis, and the remaining platina again cupelled. He took thirty grains of crude platina, and thrice as much of the combination of silver with marine acid, called *luna cornea*. The mixture being exposed to as great a heat as a glass retort would bear, no liquid passed into the receiver, but a little white matter sublimed into the lower part of the neck of the retort, as commonly happens when *luna cornea* is exposed to such a heat by itself. The mixt run clean together into a dark yellow hyacinth coloured mass, and appeared well united: the glass was stained of a dark yellow. The mixt was pounded, along with pieces of the glass, which could not easily be separated, in a clean iron mortar, the powder mixed with two ounces and a half of granulated lead, and melted in a crucible with a strong fire: the scoria was greenish. The metal, worked on a cupel, drove well, as in the common silver assay, till towards the end of the process, at which time it came asunder, grew flat and rough, and looked like silver sprung on the cupel by being too hastily cooled, but without the least metallic brightness on the surface: it was very brittle under the hammer, but bore to be filed, and the mark of the file looked white: it weighed a hundred and ten grains. It was cupelled with an ounce more of lead, and the product was the same as before, with the loss of seven grains in weight. This last bead was beaten in pieces, mixed with six drams of pure nitre, and melted  
with



with a strong fire: the metal was of a silver whiteness, and weighed seventy grains: the scoria was caustic, liver coloured, and when liquefied in the air looked greenish. The regulus was melted again, with half an ounce of the purest nitre and a dram of borax: the scoria proved cloudy, inclining to yellow underneath and to greenish above: the regulus was of a fine white, and weighed still seventy grains; it had something particular in its appearance on the surface and about the sides, resembling the radiated cobalt; it stretched pretty well under the hammer, and bore to be flatted into a thin plate, but was harder than fine silver. A part of this plate was digested in purified aquafortis: the menstruum became first of a high grass-green colour; afterwards, in a boiling heat, the plate grew black, and the solution brownish. The silver being at length dissolved, there remained at the bottom a black ponderous matter like calx of gold. This was thoroughly washed with hot distilled water, then dried, and made red hot, but it received no gold colour. It was mixed with granulated lead, and the mixture worked first on a scorifying dish, and then on a cupel: there remained a convex bead; without metallic lustre, which sprung under the hammer, and resembled the other beads obtained by cupelling platina with lead.

13. It appears upon the whole, that Marggrafs trials for working off lead clean from platina, succeeded no better than Scheffers and mine, so much of the lead being always retained as to make the metal very brittle, whereas platina by itself, whether in its crude state of grains or when melted by a burning-glass, is of considerable malleability. Macquer and Baumé made another effort: they were “ desirous of seeing, whether a heat of a good deal longer continuance would not produce that, which one *coup de feu*, perhaps more strong but of shorter duration, had

had been unable to produce. They put upon a cupel of a proper size one ounce of platina and two ounces of lead, and having placed the cupel in a furnace like that of Mr. Pott for the vitrification of earthy bodies, they raised the fire by degrees, and kept it up without intermission for fifty hours, in such manner, that during the last twenty-four hours it continued in its full violence. The cupel being then taken out, they found that the platina, instead of being in a round brilliant button as gold and silver are after cupellation, was extended and flattened on the cupel: its upper surface was tarnished, dark coloured and wrinkled, from whence it was judged at first that the operation had succeeded no better than those we have been speaking of: the platina parted easily from the cupel, which was become very hard, of a yellowish white colour, semitransparent, and struck fire freely with steel. But upon exactly weighing the platina, they found, that instead of receiving an augmentation of weight from some of the lead remaining undestroyed, it had lost one sixteenth of its weight: its lower surface was white and silvery: finally it was not eager, but bore very well to be extended under the hammer: they dissolved a part of this cupelled platina in aqua regia, and this dissolution did not shew any vestige of lead."

As Mr. Macquer appears to have employed in this experiment the platina such as he received it, containing a large admixture of ferruginous and other foreign matters undoubtedly destructible in the process; it is obvious that it might have retained a very considerable proportion of the lead, notwithstanding the diminution in weight. Nor can aqua regia be looked upon as an infallible test of its having been pure from lead; for this menstruum, in certain circumstances, will dissolve lead as well as platina. But whatever might be in this, the event of the experiment, in regard to the malleability of the cupelled mass, appeared

too interesting to be passed over, in this history, without being verified by further trials.

14. Having at hand a wind furnace, formed of a mixture of Sturbridge clay and powdered glass-house pots, secured by iron hoops on the outside, about two feet high from the grate to the top of the dome, fourteen inches wide in the middle and ten inches at the grate, with a chimney of nearly half the diameter of the grate and fourteen feet high; I first made trial of this furnace, and found its effect to be such, that there was no occasion to have recourse to any other. I fitted into it a muffle, in the manner described by the ingenious author in a memoir on the vitrefication of clay with chalk, formed of the same composition with the furnace, two inches high, three inches wide, of such length as to reach across the furnace, supported at the height of five inches above the grate by a brick of fire-standing clay, which was cut sloping downwards so as to cover as little as possible of the grate.

15. A large cupel having been kept red hot in the muffle about an hour; two ounces of lead were put in, and one ounce of the picked grains of platina dropt into the melted lead. The fire being raised with coaked pitcoal to its greatest vehemence, the whole internal part of the muffle appeared of a dazzling brightness, and the cupel could not be distinguished, till cold air was suffered to pass through by keeping the door open for some time, which was done frequently, to promote the scorification or dissipation of the lead. In this state the heat was continued, untill, in five or six hours, penetrated by the vitrescent cinder of the coal, the muffle begun to fail: all its back part, and some of the internal part of the furnace, melted, forming partly irregular vitreous lumps, and partly running down through the grate in large drops of black hard glass. The cupel was hard, yellowish white, and semi-transparent,

transparent, like Macquers. The platina was in a flat cake, coated with the semivitrified matter of the cupel and glassy drops from the muffle, so that nothing could be judged from the weight: it broke pretty easily under the hammer, and did not seem to differ from that of former cupellations.

16. What was here wanting in the continuance, I endeavoured to supply by a repetition of the fire. The platina, pounded and washed, was placed under a fresh muffle, on a scorifying dish; and the heat kept up in its full violence, chiefly with wood and charcoal, for fourteen hours. Greatest part of the platina stuck so firmly to the dish, in virtue of part of the lead which had exuded and vitrified, as not to be got off without pounding the vessel. Where the platina on the dish was struck with a hammer, or rubbed with a steel burnisher, it stretched, and acquired a continuous surface like silver or tin leaf. After the powder had been passed through a fine sieve, and washed, on beating it again some broad flat grains appeared, which stretched easily under the hammer, and on being squeezed with a pair of plyers, bent almost double: one of these bore to be opened, and bent again in several directions, without cracking. This powder, whose particles appeared so ductile and flexible, I tried to reunite into a mass, by urging it with a vehement fire, in a covered crucible, for four hours: it cohered into a button, of the form of the crucible, not at all sticking to the vessel, and free from discolourment: the button broke from a blow or two of a hammer, but not very easily, filed tolerably smooth, and burnished like fine silver.

17. I cupelled four parcels of platina, with thrice their quantity of lead, till they would no longer continue fluid in a good assay furnace; and repeated the cupellation on fresh cupels, with the same quantity of lead, a second and  
a third

a third time. The first cupels were tinged of a deep rusty colour, probably from the iron matter in the platina; the others only yellowish, as from lead alone. The plates of metal, after the first cupellation, were dull coloured and stuck to the cupels; after the others, they were brighter and did not stick. The four plates, weighing 3031 grains, kept for twelve hours on a scorifying dish, in as strong a fire as could be excited in the assay furnace, became whiter, and lost 218 grains: the white dish was covered all over with a yellow glazing. The plates, which had suffered no appearance of fusion, and which still proved brittle though much less so than before, were broken into smaller pieces, and set on four cupels, under a muffle, in the wind-furnace above described: during eight hours vehement fire, the two cupels in the fore part of the muffle, which was less hot than the back part, were observed, as often as the door was kept open for a little while, to smoke considerably; but all the air that could pass into the muffle, did not so far diminish the dazzling heat, as that any fumes could be distinguished in the back part. The arch and further end of the muffle were found all over glazed by the fumes; the cupels friable and unstained; the metal of a silver whiteness, and diminished 105 grains. The pieces in the front cupels were still brittle; those in the further ones bore to be flattened considerably under the hammer, and seemed nearly as soft as alloyed silver.

18. I made many other cupellations of the same kind; of which, as no other remarkable phenomena occurred than have been already mentioned, it would be unnecessary to give a particular detail. They agree in establishing an important fact, that though in the common process of cupellation, even when performed with stronger fires than the cupelling furnace can give, and continued some hours beyond the time in which the fixing of the

metal seems to shew that the fire has produced its full effect, platina has been always found to retain so much of the lead as to break under the hammer; yet by continuing these vehement fires for twenty hours or more, so much of this retained lead is separated, as to leave the platina malleable. Much of the lead was forced out after the metal had become solid, as appears in the experiment, No. 17, in which the quantity expelled from the cupelled plates, without their having anywise softened or altered their figure, amounted to above a tenth part of their weight. The thinner the metalline plates, the sooner and more effectually were they freed from the lead, and rendered malleable: in one cupellation, a part of the metal having run into the form of a fine wire, this wire, after six hours strong heat, proved so flexible, as to bear bending backwards and forwards several times without breaking, while a thick piece of the same mass, after eighteen hours longer continuance of the fire, was still brittle: when a small quantity of platina, worked in a cupel of a proportionate size, had, from the shape of the vessel, formed a pretty thick mass, which was the case in most of the first cupellations (No. 1 to 8 of this article) a vehement fire, of much longer continuance than that of Macquers experiment, was insufficient for rendering the mass malleable; but when beaten into powder and spread thin, a fire not extremely vehement, continued ten or twelve hours, made the particles of the powder so ductile, that they stretched under the pestle into fine plates like fragments of silver leaf: the powder thus flatted was remarkably soft or unctuous to the touch, like tallow; and being rubbed on paper, stuck to it, so as not to be easily brushed off, making it look like what is called silver paper. It was therefore a happy circumstance in Macquers experiment, and indeed essential to its success, that he used a considerable quantity  
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of platina so as to form a thin plate on the bottom of a large cupel. Much of the lead exudes at first in a vitreous form, and glazes or stains the dish or cupel on which the plate is exposed to the fire; but towards the end it seems to be forced out only in fume, no visible mark remaining on the vessel: in one experiment, the metal lost about a twenty-fifth part of its weight, after it had ceased to give any tinge to the cupel.

19. It may be proper to observe, that in most of the cupellations of platina with lead, especially where the quantity of the mixt was considerable, and a pretty strong fire made use of, the cupelled plates appeared of a regular and singular figure on the surface, such as no other metal or metallic mixture I know of assumes in fixing. In the middle was a broad flat-bottomed depression, with a lip or margin round it, like a common table plate; and the lip was frosted as it were with regular transverse rows of prominent dots. The smooth parts were in general soft or slippery to the touch.

#### VII. *Cupellation of platina with Bismuth.*

MIXTURES of platina with bismuth were submitted to the common processes of cupellation under a muffle, scorification in assay crucibles, and testing before the nose of a bellows. The general event was nearly the same as when platina and lead were treated in the same manner: the mixtures, which at first flowed easily, became less and less fusible in proportion as the bismuth was driven off, and at length could not be kept fluid in an intense fire, though they appeared, on weighing, to retain a considerable quantity of the bismuth. Nor could bismuth, any more than lead, be worked off clean, by the common process of cupellation, from mixtures of platina with six times its weight of either gold or silver.

When one parcel of platina was cupelled with three or four fresh quantities of bismuth, the first cupels were always tinged of a blackish rusty hue, the next paler, and the third for the most part only of the orange yellow colour which bismuth itself communicates, and which is considerably deeper than the stain imparted by lead.

In many of the cupellations, the surface of the metal was found covered with a leafy substance like deep coloured litharge; and sometimes, under the cupelled plate, there was a large quantity of rough spongy greenish matter, adhering in many parts strongly to the platina, running into cavities in its bottom, and in some places lying as it were between plates or flakes of the metal. It appeared that bismuth, in cupellation with platina, does not diffuse or spread itself so thin, or sink so deep into the cupel, as lead does; but loads the parts which it touches, in such a manner, as to be prevented from extending further, and to be collected there in its semivitrified state; sometimes lying in large quantity on the cupel, though a considerable part of the cupel at bottom was not tinged with it. This does not seem to happen when bismuth is worked off alone, and therefore probably proceeds from this metal being a less powerful menstruum than lead for the ferrugineous and other foreign matters blended with platina. Many of the cupellations however went on well, without any appearances of this kind, and yielded brittle plates, sometimes dull coloured and sometimes bright, according as less or more of the bismuth was worked off, of uneven surfaces, with large protuberances irregularly and sometimes elegantly disposed. Some of the minutes of these experiments having been lost, I cannot recollect whether it was with large, or with small proportions of bismuth, that the process succeeded best.

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From the effect of a long continuance of strong fire on mixtures of platina and lead in the preceding article, I was induced to submit to the same treatment mixtures of it with bismuth, a metal which promised to be easier separated than lead, as being itself much more easily dissipated by fire.

Some of the cupelled plates of the foregoing operations were kept for six hours, on four cupels under a muffle, in as strong a heat as could be raised in a good assay furnace. Of one of the plates a part had melted, and spread in fine silver-like leaves over the edge of the cupel: of all of them the thin edges bore to be hammered pretty well, and bent considerably before they cracked: the cupels were stained of a pale orange yellow. The plates being then urged for six hours longer on fresh cupels, in the wind furnace before mentioned, they all proved of a bright silver colour, and hammered well in the thinner parts, but still continued brittle in the thick ones: the cupels were very slightly tinged.

From the experiments related in this section it appears, that platina perfectly resists the destructive power of lead and bismuth, which, with the concurrent action of fire and air, reduce all the other known metallic bodies, except gold and silver, into a calx or scoria: that it resists antimony, by which silver as well as the base metals are scorified, and which has always been esteemed the severest test of gold: that it is not sensibly volatilized by arsenic, which in strong hasty fires carries off a portion of gold itself: that in degrees of heat considerably stronger and of longer continuance than have hitherto been employed for these kinds of operations, the platina preserves a part of those destructible metallic bodies themselves, retaining so much of them as to be rendered brittle; but that by further continuance of vehement fire, those bodies, at least lead  
and

and bismuth, may be wholly or almost wholly dissipated, so as to leave the platina in a mass, as malleable as the finest grains were separately, and perhaps more so, in virtue of their being purified in the operation from their iron or other foreign matters, as gold and silver are by the like means from all the base metals.

How far this dissipation of lead or bismuth may be practicable in the large way, or on masses of considerable thickness, cannot be absolutely determined from the experiments hitherto made, for as yet, with me at least, the process has succeeded only on thin pieces of the metal. Mr. Macquer seems to make no doubt that platina may on this foundation be rendered manageable by the workman in large, so as “to furnish us with burning concaves, specula for telescopes, an infinity of vessels and utensils for chemical and culinary uses, and almost all the works of the locksmith.” He observes that platina would for these purposes be an excellent material, “as its vivid and brilliant polish is never tarnished by any kind of rust, and as it not only resists the action of air, water, fire, acids, and the voracious metals, as well as the purest gold does, but joins to these admirable qualities a property still more precious, which is wanting to gold, viz. the force and hardness of iron.” In my experiments, the cupelled plates, both with lead and bismuth, were considerably harder than fine gold or silver, but softer than iron: the hardness here attributed to them appears to be inferred from the experiment on precipitate of platina related in page 505.

## S E C T. VIII.

*Of the Affinities of platina.*

**I**N this section it is proposed to give an account of such experiments as have been made relative to the comparative affinities of platina and other metals, to one another, and to saline dissolvents; the separation of platina from one metal by the intervention of another, or of one metal from another by the intervention of platina; the separation of platina by other metals, or of other metals by platina, from their solutions in acids. For the greater distinctness, the results of the several experiments are expressed in the respective titles, after the same manner as in the common tables of affinity. The body placed uppermost is always to be understood to have a greater affinity to that which is immediately under it, than to the third or lowermost; insomuch that if the first and third be combined together, the middle one, properly applied as mentioned in the experiment, will break their union, and throwing out the third body, join itself to the first, though the separation is not always complete. Where no such affinity, or separation, appears in the experiment, the several bodies are placed in a continued line.

I. *Mercury:*

*Platina:*

*Lead.*

ONE part of platina and about four of lead were melted perfectly together, and after the heat had somewhat abated, the fluid was poured gently, in a small stream, into three times its quantity of quicksilver heated so as to fume. On stirring them with an iron rod, a blackish powder was immediately thrown to the surface, which appeared to be chiefly.

chiefly platina. On grinding them together in an iron mortar, a fresh powder gradually separated, which, being occasionally washed off, in appearance greatly resembled the foregoing, but was found, on proper trials, to participate more largely of mercury and lead than of platina. The amalgam was of a very dull colour, and on being exposed to the fire in an iron ladle, swelled and leaped about, though the heat was scarcely sufficient to make any of the quicksilver evaporate. I therefore had the grinding continued, in a kind of mill, composed of a thin iron plate, cut into the form of a cross, and made to turn in an iron mortar: the plate was bent up nearly to the shape of the bottom of the mortar, and between two of the ends was fixed a piece of wood, the other two standing loose, and accommodating themselves to the mortar in virtue of their elasticity: the piece of wood received the end of an upright spindle, which being secured by cross pieces to keep it in the middle of the mortar, and a small weight, sometimes greater and sometimes less, placed on the top, a wheel and pulley procured a rapid motion with little labour. After constant agitation in this machine, with water occasionally renewed, for seven or eight days, the amalgam looked bright and uniform, and suffered the quicksilver to exhale freely. The mercury being all evaporated, there remained a dark grey powder, which proved upon examination to be platina with a very little lead. For a part of the powder being digested in aquafortis, a small portion of it dissolved, and the solution appeared to be no other than a solution of lead: the undissolved part, now of a dark purplish colour, was mostly taken up by aqua regia, to which it communicated, not indeed the common hue of solutions of platina, but a kind of dull olive colour: plates of tin, however, quickly discovered that the matter dissolved was platina, by occasioning a precipitate

cipitate of the same appearance with that which tin throws down from common solutions of platina. The rest of the powder was cupelled with lead: it left a rough, flatted, bright mass, which would no longer melt, and which exactly resembled those obtained in cupelling crude platina with lead.

Mercury is supposed to have a greater affinity to lead than to any other metallic body, gold and silver excepted. In this experiment it shewed a greater affinity to platina than to lead, since it retained much of the platina, after the lead, which was at first in much larger proportion, had been almost all thrown out.

## II. *Mercury:*

*Gold:*

*Platina.*

A MIXTURE of one part of platina and two of gold, which proved very white and brittle, was well nealed, and cautiously flatted into thin plates, which were thrown red hot into boiling quicksilver. On grinding and washing with water, a powder separated, copiously at first, and by degrees more sparingly. After the process had been continued about twenty-four hours, there was no further separation, except of a little blackish matter into which a part of the mercury itself is always changed in these kinds of operations. The amalgam, which looked bright, was put into a crucible, and the quicksilver being evaporated by moderate heat, there remained a spongy mass, of a high colour, which being melted and cast into an ingot, proved very soft and malleable, and not distinguishable by the eye from the pure gold made use of. How far this process is applicable to the separation of platina from gold in the way of business, will be considered in the following section. It is sufficient here to have established the greater affinity

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of mercury, to gold than platina, and to platina than lead.

### III. *Platina:*

*Lead:*

*Iron.*

ONE ounce of a mixture of iron and platina, and two ounces of lead, were covered with black flux, and urged with a pretty strong fire, but which did not prove sufficient for the fusion of the platina and iron: the lead being poured off into a cylindrical mould, the lower part of the cylinder looked of a duller hue than the lead was at first, and proved specifically heavier, in the proportion of 11,598 to 11,386. The lumps of iron and platina were mixed with the lead a second time, and exposed to a strong fire till the whole came into perfect fusion: on cooling the crucible too hastily in water, the fluid matter exploded and threw off the cover, and the lead was found reduced into small filaments, filling the crucible, which before was not one fourth part full. The iron regulus at the bottom was in a round, smooth, very hard lump, and seemed to retain a considerable portion of the platina. The lead, melted into a mass with a little resin, appeared, from its specific gravity, and more manifestly on cupellation, to have imbibed more of the platina than the iron retained.

Cast iron being dropt into a melted mixture of platina and lead covered with black flux, and the fire kept up strong till the iron melted, most of the platina appeared to be retained by the lead, and very little if any of it to be taken up by the iron. It was judged at first that this did not happen from the platina having less affinity to iron than to lead, but from its not having come sufficiently in contact with the iron; for we have elsewhere seen that great part of the platina sinks to the bottom even of the lead, and the iron floats on the surface of the lead.

A mixture

A mixture of platina and iron was melted with thrice its weight of lead upon a cupel, and a strong fire kept up till greatest part of the lead was worked off. The remaining mass was rugged and cavernulous: in its cavities, and at the bottom, was a very considerable quantity of a dark blackish powder with somewhat of a purplish cast, which was attracted, though not vigorously, by a magnetic bar.

This experiment seems decisive of the greater affinity of platina to lead than to iron; as it shews iron, which had been previously well combined with platina, thrown out again in its metallic form by lead. It may therefore be presumed, that the absorption of part of the platina from iron by lead in the first experiment, proceeded from this superior affinity of the platina to the lead, and not, as was at first suspected, from its having an equal affinity to them both.

#### IV. *Aqua regia:*

*Zinc:*

*Platina.*

PLATINA, digested in a saturated solution of zinc made in aqua regia, did not appear in the least corroded; but zinc, put into a saturated solution of platina, soon begun to dissolve, and to precipitate the platina. The precipitate was of a brownish black colour: the liquor, after the zinc ceased to be acted on, continued yellow, a mark that the precipitation by zinc was not total, any more than by the unmetallic precipitants in section iii. Marggraf found, that when solution of zinc in aquafortis was mixed with solution of platina, an orange-red or brick-coloured precipitate fell, the liquor continuing yellow as in the other case.

V. *Aqua regia:**Iron:**Platina.*

A SATURATED solution of iron in aqua regia did not sensibly act on platina: a saturated solution of platina readily corroded iron, the platina precipitating. A good quantity of yellow ochery powder settled at the bottom, and the undissolved part of the iron appeared incrustated with a dark coloured matter: it could not be judged from the colour whether the precipitation was complete, the solutions of platina and of iron having a great resemblance in colour.

VI. *Platina:**Aqua regia and solution of iron-vitriol:**Gold.*

SOLUTION of iron in the vitriolic acid, or a solution of the common green vitriol of iron made in water, which totally precipitate gold from aqua regia, made no change in solution of platina. A mixture of platina and gold, which had been melted together and kept in fusion for some hours, being dissolved in aqua regia, and the vitriolic solution added, the gold was precipitated and the platina remained dissolved. Solutions of iron in the nitrous and marine acids did not precipitate either platina or gold.

VII. *Aqua regia:**Copper:**Platina.*

PLATINA, put into a solution of copper in aqua regia, was not sensibly acted on: plates of copper, put into solution of platina, begun quickly to dissolve, and to precipitate the platina. The precipitate was of a dark greyish colour.



colour, and was found on trial to have a considerable quantity of the copper blended with it: the liquor was of a more dusky green than solutions of pure copper, probably from its retaining some of the platina. Solutions of copper in the vegetable, nitrous, marine and vitriolic acids, mixed separately with solution of platina, produced no precipitation or turbidness: Marggraf indeed found, that with the solution in the nitrous acid, a reddish orange coloured powder was deposited after long standing, but in this precipitation the copper solution probably had no share, for the solution of platina by itself, as he observes, yields, in time, a like precipitate.

VIII. *Aqua regia:*

*Tin:*

*Platina.*

WE have seen in the third section that plates of pure tin precipitate platina, and that they do not produce with it the red or purple colour which they do with solutions of gold, but a dark brownish or olive: it must here be added, for establishing the affinity more fully, that when platina is digested in a solution of tin made in aqua regia, no precipitation of the tin, or corrosion of the platina ensues. The precipitation by tin is not total, any more than by the metals hitherto mentioned, but it may perhaps be questioned whether the matter which remains dissolved, and which gives colour to the liquor, be true platina, or the ferruginous substance that was blended with it, since in a former experiment, page 487, after the more soluble parts of the mineral had been extracted by aqua regia, the remainder, dissolved in fresh aqua regia, appeared to be completely precipitated by tin, the liquor proving perfectly colourless. Solution of tin, mixed with common solution of platina, seemed to have nearly the same effect as tin in substance:

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a dark reddish orange coloured powder precipitated, a part of the platina or its iron remaining dissolved, so as to give a high colour to the menstruum.

IX. *Aqua regia:*

*Mercury:*

*Platina.*

MERCURY, which is said to precipitate from aqua regia no one of the common metallic bodies except gold, being put into a diluted solution of platina, seemed to be in a little time corroded, and did not run freely: soon after, it appeared covered with a greyish powdery matter, which at first was apprehended to be a precipitate of the platina, but was found afterwards to be only a part of the mercury corroded: upon applying a moderate heat, the whole of the quicksilver, the quantity of which was very considerable, was dissolved, without any precipitation of the platina. This solution of the two metals, being evaporated a little so as to dispose it to shoot, yielded crystals not at all like those of platina, but in form of needles, externally of a yellowish hue: the crystals, slightly washed with proof spirit, became colourless: exposed to the fire, they emitted copious white fumes, with a hissing or crackling noise, and left a very small quantity of a reddish powder, giving a dull red stain to the tobacco pipe which served for the vessel: the crystals laid on marble, and heated almost, if not quite, to a red heat, scarcely gave it any tinge or injured its polish. It appears from this experiment, that aqua regia, saturated with platina, is capable of dissolving a considerable quantity of mercury, and that in crystallization great part of the mercury shoots before the platina.

To another quantity of solution of platina I added more quicksilver than it was capable of taking up. The platina now gradually fell down among the undissolved mercury,  
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in form of a dark brownish powder, leaving the liquor very little coloured. Platina therefore agrees with gold in having less affinity to aqua regia than mercury has, though it differs in its affinity to the mercury, gold in this precipitation uniting with the mercury into an amalgam, while platina remains in a distinct powder. This observation accounts for a phenomenon observed by Marggraf in the following experiment.

Half an ounce of quicksilver, and an ounce of solution of platina being shaken together, the mercury run sluggish, and soon after a quantity of yellowish white powder settled at the bottom. The solution being set to digest, it appeared next day somewhat greenish. The digestion was continued a day longer, and the mixture diluted with water; the clear liquor being decanted off, the matter at the bottom was thoroughlyedulcorated, and the yellowish white powder washed off from the mercury and dried. The uncorroded mercury was not of the nature of an amalgam, but run pretty freely: being distilled in a retort, it left a metalline grain behind, so small, that its appearance could not well be distinguished without a microscope, which shewed it yellow. The white powder, set to sublime in another little retort, yielded a sublimate of a reddish yellow colour in the lower part, and whiter above: there remained a little grey matter, which being pressed looked like an amalgam. It is remarkable that the mercury had here borne a very strong fire, by which the whole belly of the retort had been melted, though without any hole being made in it.

It is probable that the little yellow grain, left upon distilling the uncorroded mercury, was a particle of gold which the platina had contained; and that, agreeably to the foregoing remark, platina and gold, dissolved together in aqua regia, may be parted on this principle, the gold being

being imbibed by the mercury, while the platina is precipitated in powder, which may be separated from the amalgam by washing.

Solution of mercury in aquafortis rendered solution of platina instantly turbid, and precipitated a greyish brown powder. Solution of mercury-sublimate in water, poured into solution of platina, precipitated a red matter, with numerous bright sparkling particles, the liquor continuing yellow : the precipitate bore washing with water, without losing its red colour.

X. *Aqua regia :*

*Nickel :*

*Platina.*

Marggraf relates, that a piece of pure regulus of cobalt, or *cobald-speiße*, from the smalt works at Schneeberg in Saxony, after being repeatedly melted with glass till all its blue-colouring matter was extracted, was readily attacked by solution of platina : the regulus lost its brightness, and became black, a yellowish powder precipitated, and the liquor looked greenish.

The substance by which the platina was here precipitated, and which communicated a green colour to the liquor, I apprehend to have been the metallic body called nickel, discovered and described by Mr. Cronstedt, in the Swedish transactions for the years 1751 and 1754, one of whose characters is to dissolve green in aqua regia, whereas the regulus of cobalt, strictly so called, gives a reddish solution. Mr. Cronstedt observes, that cobalt generally contains, besides its proper regulus, or the metal which gives a blue glass, a quantity both of nickel and of bismuth : that the *speiße*, or metal which separates to the bottom of the melting-pot in making the blue glass, generally consists of all the three metals ; the cobalt-regulus and bismuth, which of themselves are averse to any union with one

one another, being rendered miscible by the intervention of nickel: that when this mixture is again melted with glass, the cobalt-regulus vitrifies first; the nickel, more difficultly calcinable or vitrifiable, preserving its metallic form to the last. It may be presumed therefore that the operations, which Marggrafs metal passed through, separated the true cobalt-regulus, and left only the nickel.

### XI. *Platina, Gold, and Aqua regia.*

INTO a saturated solution of platina made in aqua regia, Mr. Marggraf put a plate of fine gold, and digested the whole in a moderate warmth for some days: the gold was not in the least acted upon, and there was no precipitation of the platina, except that a little dark orange coloured crystalline powder settled to the bottom, which the solution of platina would have deposited by itself. The purer grains of platina were treated in the same manner with a saturated solution of gold, and with the same event, the acid shewing no disposition to quit either of these metals in order to attack the other, so that its affinity seems to be equal to both. I melted the two metals together, and digested the compound in aqua regia: the menstruum dissolved them both, but the gold most readily; for the first portion of the liquor having been insufficient to dissolve the whole of the mass, and the rest being digested in fresh aqua regia, the first solution was found to have the greatest proportion of gold, and the other of platina. When the quantity of gold was such, as to give any thing of a gold colour to the mixture, the acid soon made the plates white, by eating out the gold first. I likewise mixed together solutions of the two metals, and did not observe any turbidness or precipitation to ensue, though Mr. Marggraf found, in his repetition of this experiment, a reddish orange coloured precipitate: in this respect variations may happen

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from the nature of the aquæ regiæ made use of; as from an over-proportion of sal ammoniac in the aqua regia in which the gold is dissolved, for sal ammoniac, as we have formerly seen, is of itself sufficient to precipitate a part of the platina. Though I could not perceive any separation on mixing the two solutions, yet on diluting the mixture with water, and suffering it to stand for some days, a bright gold coloured pellicle was thrown up to the surface: that this, however, was owing to the action of the platina, I will not affirm; for I have seen a like separation from diluted solutions of gold alone. Another mixture of solutions of gold and platina was evaporated a little, so as to dispose it to shoot: it yielded first fine red crystals, which seemed to contain chiefly gold, with very little platina; and afterwards deep saffron coloured crystals, in which the platina apparently prevailed.

## XII. *Platina, Silver, and Acids.*

PLATINA, digested in a solution of silver made in aquafortis, was not at all acted upon, as indeed might have been expected, the platina not being soluble in the acid itself by this treatment. A plate of silver, digested in solution of platina, was strongly attacked: a white calx settled upon the silver, and incrusted it all over, and the plate was so corroded as to become friable between the fingers, the liquor still continuing of a gold yellow colour. This experiment is from Marggraf: it seems to shew, that silver absorbs the marine acid from solution of platina, and that the platina remains dissolved in the nitrous acid, for if any of the platina had precipitated we may presume that the calx would not have been white. He found, however, that when the silver was previously dissolved, either in the nitrous or vitriolic acids, it then occasioned a precipitation of the platina, for on mixing these solutions with solution of platina, a yellow precipitate fell.

XIII. *Platina, Lead, and Acids.*

THIN plates of lead put into solution of platina are soon corroded, and white crystals form at the bottom with a blackish matter intermixed, the liquor continuing yellow: the crystals dissolve in water, leaving the blackish powder, which appears to be platina. Marggraf, from whom this experiment is taken, tried also solutions of lead, made both in aquafortis and in distilled wine vinegar, and relates that on mixing these solutions with solution of platina, no precipitation ensued; a phenomenon not a little remarkable, as solutions of lead, made in either of the above menstrua, are in general precipitated by aqua regia or liquors containing the marine acid. If there was no error or deception in these experiments, it might be concluded from them, that the marine acid has a greater affinity to platina than it has to lead; but with me the event was otherwise. A solution of lead in aquafortis, and a solution in distilled water of crystallized saccharum saturni which I had prepared myself, being dropt into separate portions of solution of platina, the first drops produced no apparent change, but on continuing to add more of the lead solutions, both mixtures grew turbid and milky, and deposited quickly very copious white precipitates, the liquors continuing yellow like diluted solutions of platina. I repeated the experiment three or four times with different solutions of platina, and the appearances were always the same.

XIV. *Platina, Regulus of antimony, and Aqua regia.*

MARGGRAF found, that a piece of pure regulus of antimony, digested in solution of platina, was attacked by the acid. A good deal of white powder settled at the bottom, which was doubtless for the most part some of the regulus corroded: the rest of the regulus was reduced into small

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brilliant parts, and appeared to be intermixed with precipitated platina: the liquor continued yellow.

XV. *Platina, Bismuth, and Acids.*

THE author above-mentioned relates, that on digesting bismuth in solution of platina, the effect was nearly the same as with regulus of antimony, the bismuth appearing corroded, a white powder settling at the bottom, and the liquor continuing yellow: and that solution of bismuth in aquafortis being mixed with solution of platina, no precipitation happened.

The experiments in the five last articles of this section are too obscure and ambiguous for points of such importance as the affinities of bodies to be established on them; but those of the first ten seem to be sufficiently clear and decisive. It may be observed, that in some of these affinities platina agrees with gold, as in being precipitated from aqua regia by zinc, iron, copper, tin, and quicksilver; but that in others, it differs so essentially from gold, that when the two metals are intimately combined together by long fusion, they may still be parted from one another in virtue of this contrariety in their affinities to particular bodies, platina being rejected by quicksilver while gold is retained, and gold being rejected by aqua regis, when vitriolic solutions of iron are added, while platina is retained.

S E C T. IX.

*Of distinguishing and purifying Gold mixed with Platina.*

WE have now finished a laborious examination of the properties of this new metal and its relations to other bodies. One of the most important advantages, that were expected to result from this enquiry, considered in a commercial view, was the preserving of the fineness and value



value of gold; or preventing it from being fraudulently debased, by the admixture of a body, endowed with so many of what have been universally reckoned the most peculiar and inimitable characters of the precious metal. This advantage has been obtained in the most ample manner that could be wished for; the experiments having pointed out different means, by which small proportions of platina mixed with gold, or small proportions of gold mixed with platina, may be easily distinguished, and by which the two metals, however blended together, may be easily parted from one another, either in the way of assay, or of business in large. The principal of these means it will here be proper to collect together from the different parts of the history, and to consider them more particularly in regard to their use and application in practice.

### I. *Amalgamation with Quicksilver.*

IN an experiment related in the last section, page 579, a mixture of platina and gold being united with mercury, and the amalgam ground with water for a considerable time, the platina was gradually thrown out, and the gold retained by the quicksilver.

This process, simple and convenient in the execution, is accompanied with some uncertainties in regard to its effect, which render it of less general use than it may at first promise to be. Repetitions of the experiment have shewn, that though the separation succeeds in some cases, it does not perfectly in all: that if there is any particle of the platina not fully dissolved by the gold, which will generally happen unless the quantity of gold is three or four times greater than that of the platina and the mixture is melted with an intense fire, this part will be retained in the amalgam, not dissolved by the mercury, not comminuted by the pestle, and too ponderous to be washed off in  
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its gross form. Various mixtures of platina and gold were treated in the manner above described; and the gold, recovered from the amalgams, was submitted to further examinations. Where the proportion of platina was large at first, the microscope almost always discovered some grains of it remaining with the spongy mass of gold after the evaporation of the mercury; and even when the gold had been melted, and made fluid enough to be poured into a mould, I have sometimes seen distinct grains of platina on the fracture of the ingot. Where the proportion of platina had been small, the recovered gold was frequently, but not constantly, found to be pure.

It appears therefore, that though mercury has a greater affinity to gold than to platina, and though platina, on this principle, is capable of being separated from gold; yet the process is too vague and precarious to be applicable in the way of assay, as we can have no mark of the precise time for discontinuing it, and as we can never be certain, without making another assay, whether the whole of the platina is separated or not. As a preparatory operation, where the quantities of platina and gold to be parted are large, it is nevertheless of good use; as greatest part of the platina may by this means be washed over with little trouble, and the gold brought into a less compass, so as to be commodiously submitted to a further purification by the means hereafter pointed out.

This process may be considered as answering the same purpose, in regard to mixtures of gold and platina, as that of stamping and washing does in metallic ores, which could not be reduced to pure metal in the furnace to advantage, without the previous separation of great part of their earthy or stony matter by water. To ensure success, the mixt, if brittle enough to be pulverable, should be reduced into very fine powder, in stamping mills, or in an iron mortar:

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the pulverisation may be facilitated by means of heat, both the grains of platina itself, and mixtures of them with other metals, being considerably more brittle when hot than when cold. Or what is still better and easier, the mixt may be melted with a suitable quantity of lead, and this compound submitted to the trituration with mercury and water. If there is any truth in the report, that certain gold mines are neglected, on account of their intractableness from platina contained in them, this last process may turn out a very important and advantageous one.

## II. *Precipitation by vegetable fixt Alcalies:*

As gold is totally precipitated by fixt alkaline salts, but platina only in part, and as a minute portion of platina, remaining dissolved tinges a surprizingly large quantity of the fluid of a yellow colour; it was presumed that a small admixture of platina with gold might by this means be readily discovered. A few drops of a solution of platina were therefore mixed with above a hundred times the quantity of a solution of gold, and a pure fixt alkaline salt gradually added so long as it occasioned any effervescence or precipitation. The remaining liquor was still so yellow, that it was judged the platina would have discovered itself, though its proportion had been less than one thousandth part of that of the gold. It may be observed, that though it is customary to dilute metallic solutions pretty largely with water in order to their precipitation, yet here, as we want only to see whether any colour remains in the liquor after the precipitate has settled, the less dilute the liquor is, the less quantity of colouring matter we shall be able to distinguish.

It has been objected to the above experiment, that though the platina is discoverable when thus mingled superficially

perificially with the gold, it may nevertheless, when combined more intimately by fusion, elude this method of trial. Mixtures of gold with small proportions of platina were therefore kept in fusion for several hours, with a very strong fire, and afterwards dissolved in aqua regia. The solutions were diluted considerably with water, and a solution of pure fixt alkaline salt gradually added, so long as any effervescence or turbidness ensued. The liquors proved paler than when the two metals had been dissolved separately, but retained colour enough to betray the platina. As the degree of colour was not here so great, as might have been expected from the quantity of platina which there was reason to believe they contained, I tried to discover the platina in them by some character more conspicuous. I put into the filtered liquors some plates of pure tin: the tin presently contracted an olive hue, and threw down a large quantity of brownish precipitate, as it does from the common solutions of platina: it was observable, that the tin plates were often sensibly acted upon even while the liquor was overcharged with alkali.

It has been further suggested, that since a part of platina is precipitated as well as gold by fixt alkaline salts, if only this part be mixed with gold, it will elude this trial, and be thrown down by alkalies again, along with the gold, from the solution of the compound. To determine this point, I melted with gold a precipitate of platina made by fixt alkali, and kept them in strong fusion for an hour and a half: they seemed to unite more easily than gold does with the crude platina, and formed a smooth neat bead, which hammered pretty well into a thin plate before it cracked, and appeared internally uniform and equal. This compound being dissolved in aqua regia, the solution diluted with a little water, and a solution of fixt alkaline salt added by degrees till the acid was more than saturated,

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the liquor became, not indeed colourless, but so pale, that it could hardly be judged to contain any platina : nevertheless, on putting into it some tin plates, they quickly shewed, as in the foregoing experiment, that it held a very considerable quantity of platina. It appears therefore that in all these circumstances the platina remains partially dissolved in the neutralized liquor ; and that on this foundation, small proportions of it, mixed with gold, may be discovered, either by the colour of the liquor after precipitation with alkali, or, in a more sensible manner, by further precipitation with tin. In all the above experiments the solutions were diluted with water, not as being a circumstance advisable where gold is to be thus examined, but that the usefulness of this way of trial might be established with greater certainty.

Volatile alkaline salts or spirits have the same effects as the fixt alcalies on solutions of platina, but their effects on solutions of gold are in some circumstances different. After the acid has been satiated, and all the gold precipitated, an addition of the volatile alkali beyond this point redissolves some part of the gold, so that the liquor becomes yellow again though there be no platina in it. For this trial therefore, only the pure fixt alcalies are to be used, which, in whatever quantity they are added, have not been found to redissolve any of the gold.

### III. *Precipitation by mineral fixt Alkali.*

THE vegetable fixt alcalies serve only for distinguishing whether gold is mixed with platina or not : they are insufficient for the purification of the precious metal, as they always precipitate a part of the platina along with the gold. With the mineral alkali, or the alkaline basis of sea salt, the case is otherwise. Though this alkali, as appears from Marggrafs experiments, precipitates, equally with

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the vegetable, all the common metallic bodies, gold, silver, copper, iron, tin, lead, zinc, bismuth, regulus of antimony, cobalt, &c. yet in solution of platina it produces no precipitation or turbidness; so that when this alkali is mixed with a solution of gold containing platina, the gold alone is precipitated, and all the platina remains dissolved. The manner of obtaining this alkali from the acid with which it is united in sea salt, as it would in this place too much interrupt the history, is referred to the appendix.

The mineral alkali is in many places, particularly in the eastern countries, found native, either in a pretty pure state, or blended chiefly with earthy substances, from which it is easily separated by solution in water. I have been favoured by Dr. Heberden with a quantity of this native salt sent to him from Teneriff, and find that it answers the present intention as effectually as the alkali extracted from sea salt. The solution of platina effervesced with it, but in whatever proportions the solution of the alkali and of the platina were mixed together, I could not observe the least precipitation or cloudiness.

A salt of the same nature, though generally perhaps mingled with some foreign saline matters, is obtained from the ashes of certain plants, called Kali, which growing chiefly in salt marshes or on the sea shore, the marine salt is supposed to be imbibed by them, and to be decomposed, or to have its acid separated, partly by the power of vegetation in the plant itself, and partly by the burning. The best sort of these ashes is said to be prepared at Alicante in Spain, from an annual procumbent kali with short leaves like those of houseleek. The ashes, which are one of the common kinds of potash in France, and there called *soude* or *soda*, are brought to us, under the name of *Spanish ashes* or *bariglia*, in hard spongy masses, partly whitish or grey, and partly blackish. From these masses the saline  
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part is extracted pure by powdering and digesting them in water. Though it might be suspected that this salt, in virtue of its containing not only the mineral but a portion of vegetable alcali, would precipitate part of the platina as well as gold, I could not find that solution of platina suffered the least alteration from it, any more than from the native or marine alcalies.

How far these salts may suffice, for the perfect separation of platina and gold that have been intimately combined with one another by fusion, I have not yet had direct experience. But it may be proper to observe, that though both the native alcali and bariglia are supposed generally to contain some sea salt in its whole substance, which for some purposes renders them unfit, yet this salt does not appear to be here of any disadvantage, for pure sea salt occasioned no precipitation or turbidness in a solution of platina, any more than in solution of gold. The platina employed in these experiments was such as had been cupelled with lead and urged afterwards with repeated strong fires, page 570.

#### IV. *Precipitation by sal ammoniac.*

THE alkaline salts in the two foregoing articles precipitate the gold, and leave the platina wholly or partially dissolved in the liquor. Sal ammoniac has a contrary effect, precipitating great part of the platina, and leaving all the gold dissolved; and on this principle platina may be discovered in gold as readily and as effectually as on the other. The metal being dissolved in aqua regia, add a little solution of sal ammoniac made in water: if the gold contained any platina, the liquor will instantly grow turbid, and a fine yellow or reddish precipitate will quickly fall to the bottom: if the gold was pure, no precipitation or change of transparency will ensue.

V. *Separation by inflammable liquors.*

INFLAMMABLE spirits, which revive gold from its solution in form of yellow films, have no such action on solution of platina. This experiment affords a sure criterion for distinguishing whether gold has been debased by platina, or whether platina holds any gold, and likewise an infallible method of recovering the gold perfectly pure. If the compound be dissolved in aqua regia, the solution mingled with twice its quantity or more of rectified spirit of wine, and the mixture suffered to stand for some days in a glass slightly covered, the gold rises to the surface, leaving the platina dissolved. The golden pellicles may be collected, by pouring the whole into a filter just large enough to contain it: the dissolved platina will pass through, leaving the gold upon the paper, which is to be washed with fresh portions of hot water till the liquor runs through perfectly colourless. The paper is then to be squeezed together, and burnt in a crucible previously rubbed on the inside with chalk, which prevents the small particles of the gold from lodging in the cavities: when the matter has fully sunk down, some nitre is to be added, and the fire increased to bring the gold into fusion. This process is accompanied with one inconvenience, the slowness of the separation of the gold from the solution: this may be somewhat expedited, by employing a spirit that has been distilled off from such vegetables as give over an essential oil.

The same intention is answered very speedily, by pure essential oils. The metal to be examined being dissolved in aqua regia, add to the solution about half its quantity of any colourless essential oil: shake them well together, and then suffer them to rest: the oil rises immediately to the surface, carrying the gold with it, and leaving the platina



platina dissolved in the acid underneath. The oil, loaded with the gold, appears of a fine yellow colour, and on standing for a few hours, throws off great part of its metal in bright films to the sides of the glafs. The oil may be taken off from the acid before this separation happens, well shaken with water to wash off such parts of the platina as may adhere to it, and then set on fire in a crucible: when thoroughly burnt out, the residuum is to be melted with nitre as in the preceding experiment. After the separation of the oil employed at first, it may be proper, for the greater security, to add a little more; which, if any part of the gold should have been left in the acid, will effectually take it up.

The gold is taken up still more readily, and perhaps more perfectly, by the subtle fluid called æther or æthereal spirit of wine, the preparation of which has been already described in the history of gold. Though this fluid is too expensive to be employed for the purification of gold in the way of business, it may be of use in the assaying of gold suspected to be debased with platina. Indeed the purifications by the common vinous spirits and essential oils are not to be recommended to the refiner, who can better avail himself of the method pointed out in the following article.

#### VI. *Precipitation by green vitriol.*

THE most effectual and advantageous method of purifying gold from the metallic bodies commonly found mixed with it, appears to be, by dissolving it in aqua regia, and precipitating with a large proportion of a filtered solution of green vitriol. Happily the same process purifies it from platina; the vitriolic solution precipitating the gold and leaving the platina dissolved. See the history of gold, page 160 of this volume. On many repetitions of this experiment, with mixtures of different proportions of the two metals,

metals, I could never find that any part of the platina was precipitated with the gold, or that any part of the gold continued dissolved with the platina.

Mr. Scheffer was the first who discovered this property of platina, of not being precipitated by green vitriol; and the important consequence of it did not escape him. He seems to think however, that the precipitation of the gold by vitriol, and washing the precipitate thoroughly with water, are not sufficient for completely purifying the gold from the platina, and directs an additional operation, the amalgamation of the washed precipitate with mercury; a process which did not appear to me to be at all needful.

## S E C T. X.

### *Experiments on the yellow particles mixed with platina.*

**T**HE yellow particles, intermixed with platina as it comes to us, were not only by me, but by every person I know of who had examined this mineral, taken to be gold; except only Mr. Marggraf, who says they looked like the finest gold, but no where hints that they were gold, and even relates some experiments which seem to prove that they were not what they appeared to be.

“ On some of these yellow grains, in a parting-glass, he poured aqua regis, and set them in digestion together. But though the aqua regis was made to boil, the grains were very little acted on, the liquor hardly receiving a yellow tinge, and solution of tin precipitating nothing from it.”

“ Having picked out the yellow grains from some platina that had been treated with arsenic, sal alembrot, &c. he mixed them, their quantity being but small, with half a dram of lead, and cupelled them with the lead: the process being finished, the remaining button was greyish-black, flatted, and cracked about the edges, like those obtained

tained in the cupellation of crude platina, and weighed about half a grain. This little bead was put upon a fresh cupel, with one grain of gold that had been parted with silver, and twenty grains of granulated lead: after cupellation, he had a fair gold button, yet still somewhat flat, curled, and with a kind of net-work on the surface, in colour like gold but paler, weighing exactly two grains, hard indeed, but bearing pretty well to be reduced into plates. To this he added four grains of the finest laminated silver, and twenty grains of granulated lead; and on repeating the cupellation obtained a button not yet quite round, and weighing five grains. He flattened it, for it was considerably malleable; made it red hot; and tried to part it with purified aquafortis: but the aquafortis, though made to boil, would not sufficiently act on it. He therefore poured off the aquafortis, and found the plate very little corroded. After washing it several times with distilled water, and heating it red hot, it weighed four grains, and was found to be brittle, and just perceptibly yellowish. He added to it six grains more of fine silver, with twenty grains of granulated lead, and cupelled again: the button weighed thirteen grains, and consequently had gained an increase of three grains. It was very malleable, and being flattened, made red hot, and digested in purified aquafortis, the aquafortis attacked it briskly, leaving some black plates, which being washed, and ignited under a muffle, appeared of a fine gold colour, and weighed one grain."

In this last experiment it is probable, that the smallness of the quantity occasioned some deception. If we conclude from it, that the yellow particles were not gold, because the gold that was melted with them was recovered without increase; we must conclude for the same reason, either that they were not platina, or that the platina was destroyed in the cupellation or dissolved by the pure aquafortis. The  
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experiment with aqua regis seems liable to the same difficulty; for if the yellow grains were not gold because they did not dissolve in aqua regis, for the same reason they either were not platina, or platina did not dissolve in aqua regis.

I have already mentioned the facts which induced me formerly to believe that the yellow particles mixed with platina are really gold: see page 487. I have since repeated those experiments with the same event, and made another which may perhaps be thought more decisive.

Twelve ounces, or 5760 grains, of platina rich in yellow particles, were placed in three scorifying dishes under a muffle, and kept of a strong red heat for two or three hours, in order to dissipate any mercurial or other foreign matter by which some of the yellow grains might be enveloped. All the yellow particles, that could be distinguished by a good magnifying glass, being then picked out, which employed two persons for seven or eight hours, their weight amounted to 47 grains: some of them were all over yellow; others were in part yellow, and in part like the grains of platina.

These picked particles were cupelled with somewhat more than thrice their weight, viz. 150 grains, of lead, which in six different assays had yielded a silver bead amounting to between a 9525th and a 9527th part of its weight. The cupelled mass was of the shape of a kidney-bean, grey, rough, brittle, with a cavity in the internal part corresponding to the shape of the outside. The mass, broken in pieces, was laid on a fresh cupel, and urged with a very strong fire for five or six hours. It was less brittle than before, filed smooth, and appeared of a pale yellowish colour.

The metal being then digested and boiled with aqua regia in a Florence flask, greatest part of it dissolved, a small quantity

quantity of whitish powder, probably silver, remaining at the bottom of the vessel. The gold-coloured solution being poured into a solution of green vitriol, a precipitate like that of gold soon fell. After standing till next day, that the precipitate might fully settle, greatest part of the liquor was decanted off, and the remainder, with the precipitate, poured upon a filter: when the liquor had run through, the powder was washed on the filter with fresh portions of water. When dry, the filter with the precipitate were put into an assay crucible, and kept red hot till no more flame or smoke appeared. Some nitre was then thrown in by little and little: at first a slight fulguration arose; at length the whole appeared in quiet fusion, and being poured out into a mould, I obtained a lump of high coloured, malleable, pure gold, weighing between eighteen and nineteen grains.

## S E C T. XI.

### *Of the mineral history of Platina.*

**O**F the mineral history of this metal very little is as yet known with any certainty. Though new to Europe, the history even of its discovery is as obscure as that of the metals of most ancient use: it may be presumed, that the little advantage which promised to result from it, on account of its want of fusibility, occasioned it at first to be neglected; and that the fraudulent purposes, to which it was afterwards found to be applicable, occasioned the knowledge of it to be concealed.

It is supposed by some, that platina is the produce of the East Indies as well as of the West, and that its analogy with gold has been known also for a considerable time in the former as well as in the latter. The foundation of this suspicion is, that the late professor s'Gravesande had in his  
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possession a ponderous metallic body, reckoned heavier than gold, supposed to be a mixture of gold and platina, said to have been brought by the Dutch East-India ships from China, and to have been there sold at a high price. Dr. Brownrigg however informs me, that having lately made enquiries about this substance in Holland, he learnt from professor Allamand, that it is indeed a mixture of platina and gold, but that there was a mistake in regard to the place it had come from, which was not the east but the west Indies.

That the platina brought into England is the produce of the Spanish west Indies, appears unquestionable; but in what particular places or in what form it is met with, is far from being clear. Some speak of its being found in great abundance, like sand, in certain rivers in the province of Quito. A person who had been upon the spot informed me, that it came from the mountains near Quito, or between Quito and the South sea; that great part of the land at the bottom of those mountains is covered with it, the floods, which come after heavy rains, washing the mineral down with them. Another person, concerned also in the importation of it, affirmed that it was found in Peru, in a gold mine, which had been formerly destroyed by an inundation and lately drained; whether originally contained in the mine, or brought by the flood, was not known.

It has been reported, and without contradiction, ever since the platina became known here, that in order to prevent the frauds which might be practised with a substance of such qualities, the king of Spain had ordered the mines that afford it to be stopt up; an account which, if literally understood, seems to imply that platina is not plentiful on the surface of the earth. Whatever may be in this, whether the prohibition was made against the working of  
mines

mines of platina, or the exportation of platina lying at day, or both; we may observe, that the setting at large even of the little quantity that has hitherto been made publick, far from being productive of any ill consequences, has been the means of effectually preventing those abuses, which platina could not fail of giving occasion to, while confined to a particular part of the world, and while the existence of such a substance was in general unknown. In the papers laid before the royal society soon after the platina came here, there is an account of gold having been taken in payment from some Spaniards, which being mixed with platina was so brittle that it could not be disposed of, and which could not be refined in London, so that it was quite useless. I have been informed that the Dutch refiners at Dort have long complained of their meeting with gold adulterated with a substance which they could not separate, which they called *diabolus metallorum*, and which they now judge to have been no other than platina; and that our jewellers, &c. for many years past, have avoided making use of the Spanish gold for any curious works, on account of its having frequently a mixture of a substance which renders it intractable, and which is often visible to the eye in small distinct grains like those of platina, as if the gold had been melted by a heat not sufficient for the perfect dissolution of the platina; which when dissolved would have given an ill colour to the mass (see page 526). The more the platina became known, the less danger there was of any frauds of this kind, and we have now nothing to fear from it; the experiments already made having discovered easy means of distinguishing with certainty gold debased by platina, and of completely parting the two metals, however they may be blended together by accident or design. The refining of gold from platina is now no more difficult than the refining of it from any other metal.

It is the general opinion that platina is found in the same form in which it is brought to us. The observations on the appearance of the grains, and the matters mixed with them, mentioned at the beginning of this essay, induced me, on the first examination of it, to think that it had been ground in mills with quicksilver. Marggraf, whose platina came from London, and probably from the same parcel with that in which I had observed the drops of quicksilver, seems to have entertained a suspicion of the same kind; for he doubts whether the platina is a native mineral, or a metallic recement from which the Spaniards have extracted the perfect metal it contained. I have since been informed that the quicksilver we observed among it, which doubtless influenced Marggraf as well as me, did not come with it from the west Indies, but was added here by the proprietor with a view to get out the golden particles.

Some accounts however seem to countenance the above conjecture, that platina is found in large masses, and is reduced into smooth grains by stamping and grinding. A substance in small grains, like the platina as brought to us, one should think could hardly be called a stone, as platina is by don Antonio d'Ulloa.

D'Ulloa is the first writer I have met with who mentions platina by name. In his voyage to South America, in 1735 and the following years, speaking of the gold and silver mines of Quito, he relates, that in the territory of Chocò there are mines, in which the gold is so enveloped in other mineral substances, bitumens, and stones, that they are obliged to use quicksilver for its separation; that sometimes they find mineral substances which, from their being mixed with platina, they chuse to neglect; that this platina is a stone (*pedra*) of such resistance, that it is not easily broken by a blow upon an anvil; that it is not subdued by calcination; and that it is very difficult to extract the metal it contains even with much labour and expence.



Some have suspected that the *pedras del Inga* or *Inca*, described by the same author as being untransparent and of a leaden colour, and which were made into mirrors by the ancient Indians, consist of platina mixed with a stony matter. This mineral cannot be the same with that to which he gives the name of platina in the foregoing paragraph, for he expressly mentions that the *pedra del Inga* is soft, and liable to be broken by a slight blow. The Inca stone is now pretty common, and as the French translator of the papers on platina (see page 447) observes, appears to be no other than a ferruginous mineral of the pyrites or rather mundick kind.

Alonso Barba mentions a substance, under the name of *chumpi*, which seems to have more resemblance to the platina of d'Ulloa. He describes the *chumpi* as a hard stone, of the emery kind, participating of iron, of a grey colour shining a little, very hard to work because it resists the fire much, found in Potosi, Chocaya, and other places, along with blackish and reddish ores that yield gold. If platina is really found in large masses, either generally or only now and then, one might reasonably expect those masses to be such as are here described.

Of the same kind perhaps also is the mineral mentioned by several authors under the name of Spanish emery, *Smiris Hispanica*, which should seem, from the accounts given of it, to be no other than platina or its matrix. The *smiris* is said to be found in the gold mines, and its exportation prohibited; to contain films or veins of native gold; to be in great request among the alchemists; to have been sometimes used for the adulteration of gold; to stand, equally with the noble metal, cupellation, quartation, antimony, and the regal cement; and to be separable from it by amalgamation with mercury, which throws out the *smiris* and retains the gold; properties strongly characteristic of  
 platina,

platina, and which do not belong to any known substance besides. This debasement of gold *per extractum smiridis Hispanici* is mentioned by Becher in his *minera arenaria*, and several times hinted at in his *physica subterranea*. Both Becher and Stahl indeed call the substance, which the gold receives from the emery, an earth, whereas platina is undoubtedly a metal; but this does not at all invalidate our supposition, for they give the name of earth also to the substance which copper receives from calamine in being made into brass, which is now known to be metallic.

From these observations I have been led to suspect that the European emerys likewise might possibly participate of platina. If this was certain, it would account satisfactorily for the use which some of the alchemists are said to have made of emerys and other ferrugineous ores; and we should no longer doubt, or wonder, that by treating gold with these kinds of minerals, they obtained a permanent augmentation; that this augmentation, though it resisted lead, antimony, aquafortis, and the regal cement, was separable, as Becher owns it was, by quicksilver; and that, when it exceeded certain limits, it rendered the gold pale and brittle.

If emery contains platina, I imagined it might be discoverable by boiling the powdered mineral in melted lead, and afterwards working off the lead upon a test or cupel. The experiment was made with eight ounces of the finest powder of common emery, and the same quantity of lead, which were covered with black flux to prevent the scoriification of the lead, and urged with a strong fire for two or three hours. The lead became hard, rigid, of a dark colour, and a granulated texture, as if it had really imbibed some platina from the emery; but in cupellation it worked almost entirely off, leaving only a bead about the size of a small pins head, which was probably no other than silver contained in the lead.

I repeated the experiment, with some variation, thinking to obtain a more perfect resolution of the emery by vitrefying it with the lead. Two ounces of fine emery, and six ounces of minium, were well mixed together, and urged with a strong fire, in a close crucible, for an hour: they melted into an uniform dark brownish glass. The glass was powdered, mixed with four ounces of fixt alkaline salt and some powdered charcoal, and put into a fresh crucible, with some common salt on the surface: The fire was pretty strongly excited, but the fusion was not so perfect as could be wished, and only about two ounces of lead were found revived. This lead had suffered nearly the same change as that in the foregoing experiment, and like it, gave no appearance of platina on being cupelled.

It seems to follow from these experiments, that the emery employed in them contained no platina; but as it is not to be supposed that all emerys are of one composition, other sorts may deserve to be submitted to the same trials. As gold is contained in some parcels of common minerals, and by no means in all the individuals of any one species; platina may possibly in like manner be found in some European ores, though there is not the least footstep of it in other parcels of the same kind of ore.

## S E C T. XII.

### *General Observations.*

**T**HE foregoing history has brought us acquainted with a mineral substance, whose metallic aspect, great weight, malleability, and perfect miscibility with all the common metallic bodies, are sufficient characters of its being a true metal: --- which abides fixt and uncalcined in the strongest fires, is nowise scorified by nitre, or by lead or bismuth, nor dissolved by vitreous bodies, and which  
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is therefore a perfect metal, of the same class with gold and silver, and perhaps more perfect, or less alterable, than they: --- which, with the colour of silver, possesses the specific weight, and several other of the reputedly most discriminative properties of gold; resisting, equally with gold, many agents, which discolour, corrode, dissolve, or scorify silver and the base metals, as air and sulphureous exhalations, the nitrous, marine, and vitriolic acids both in their liquid state and when resolved by fire into fume, and sulphur and antimony in fusion: --- with these valuable properties of gold, it adds some to gold itself, making it both less soft and less fusible, which no other alloy does: hence a due proportion of it bids fair to remove those inconveniencies, which the enamellers complain of, when they work upon plates either of fine gold or of alloyed gold.

2. Though platina undoubtedly belongs to the same genus of bodies with gold and silver, of which genus no more than these three species have hitherto been discovered; and though it agrees with gold in many properties which have been universally supposed distinctive of the species: yet there are other important characters in which it remarkably differs from gold. Its white colour; its want of fusibility; the singular alterations which it produces in some of the other metals, and in gold itself; its being difficultly and sparingly acted on by *hepar sulphuris*, by which gold is plentifully dissolved; its solution in *aqua regis* giving no stain to the substances which by solutions of gold are tinged red or purple; its being in part precipitated from its solution by *sal ammoniac*, which does not in the least precipitate gold; its being precipitated only partially by vegetable fixt alcalies and by volatile alcalies, and not in the least by the mineral alkali or by solution of green vitriol, by all which gold is precipitated entirely;

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its precipitates by alcalies having nothing of the fulminating power, which precipitates of gold possess in a more eminent degree than any other known kind of matter; its solutions in aqua regia suffering no decomposition from essential oils or æther, by both which gold is imbibed from the acid, nor from inflammable spirits by which gold is revived and thrown out in its proper form; its being rejected, on trituration, from its solution in quicksilver, while gold is retained and continues dissolved; its being separable from gold, in virtue of these diversities of affinity, without augmentation or diminution of either metal, as easily and as perfectly as any one metal is separable from any other; are characters abundantly more than sufficient for establishing a specific difference between platina and gold.

3. The author of the letter from Venice, mentioned in page 447, enters into some alchemical speculations on this subject, which the nature of the present history requires that I should give some account of. He imagines, that as platina is a species of the same genus with gold, its differences from gold are only accidental, proceeding either from some heterogeneous body radically united with it, or from the want of a glutinous tinging sulphur. To which of these causes its imperfection is owing, he does not determine: its being less ponderous than gold, the black points discovered on its grains by a microscope, and a part of it being precipitated from aqua regia by alcalies while a part continues dissolved, are brought as arguments for the former; its want of fusibility, its solution wanting the power of staining animal substances and of producing a purple with tin, and its not being separated from its solution by inflammable liquors which have an affinity with sulphurs, for the latter. In the one case by purging the platina of its heterogeneous matter, and in the other by introducing the tinging sulphur, he thinks it will become gold. This last, it seems, is easy enough to be done,

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bodies having a natural disposition and appetite for receiving the principle which is wanting for their perfection: but in the first case there are no hopes of succeeding, for to root out an impure matter, with which a metal is radically combined in its first formation, he admits not to be in the power of any other agent than the philosophers stone itself. Of these notions it is sufficient to observe, that they are drawn from a supposition which cannot be admitted till some facts shall be produced, to make it probable, viz. that all the base metals are no other than gold vitiated by some impure substance.

4. Vogel adopts an opinion, that platina is not a true metal or semimetal of a peculiar kind, but a mixed mineral, the dross of the amalgamation-works in which gold is separated by quicksilver from a mixed ore. This opinion he attributes to Marggraf; and in a periodical pamphlet published at London, it is said that Marggraf supposes platina to be not only the effect of reiterated amalgamation, but to be a part of the mercury itself fixed by some matter in the ore or metal it was amalgamated with. All I can find in Marggraf relative to this point is the following passage. "We cannot say with certainty whether platina is an actual ore, or whether it is a stream-mineral which has been torn off and carried away by water from entire veins, or whether thirdly it may not possibly be a mere metalliccrement, from which the Spaniards, as being the owners of the works, have already perhaps extracted the perfect metal." I do not apprehend that the latter part of this sentence will admit of the improbable interpretation that has been given of it. The author seems to me to have meant no more, than that the platina possibly has not come to us in its native form, but has been ground with quicksilver to extract the gold intermixed with it; a suspicion which I had myself expressed also in the first paper in the Transactions, and which the mercurial globules found among the platina could not fail to produce.

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## A P P E N D I X.

*Page 4, 5. Portable Furnaces.*

**A** CONVENIENT grate for these furnaces may be formed of four or five iron rings, placed within one another, each furnished with three pins at equal distances projecting from its circumference: the pins of the inner ring drop down into corresponding notches made in the next, and the pins of this second ring into notches in the third: the notches are made in the middle of the spaces between every two pins. Thus we have a grate composed of moveable parts, and which we can enlarge or diminish at pleasure, so as to fit into furnaces of different widths, by adding or removing a ring on the outside: the spaces for admitting air to pass up through the fuel, and the ashes to drop down, are likewise more equally distributed than in those of the common construction. I have had some iron grates of this kind cast, and find them to answer well: the rings are about five eighths of an inch deep, a quarter of an inch thick, and their distances from one another somewhat more than half an inch: the inner ring is an inch and a half in diameter, and three pins projecting inwards prevent any coals from falling through this space.

Instead of binding the black lead pots with wire, they may be surrounded with iron or copper hoops. The advantage of a hoop round the mouth has been already mentioned: another may be fitted between the doors, and as the widest part of the furnace is that included between the

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hoops, two slips of iron or copper, passing from one hoop to the other on opposite sides, and screwed to each, will keep them immovable in their places: these slips serve likewise to carry handles for lifting the furnace by.

It may be proper to observe that even the unfound or cracked pots, unfit for the purposes of crucibles, and which are sold for a much lower price than the found ones, if properly secured with hoops or wires, will make useful and durable furnaces. In all cases it will be expedient to wash over the insides with Sturbridge clay diluted with water; and where the furnace is designed for continued strong fire, or for standing the action of corrosive bodies, as in fusion *trans carbones* (page 21) it may be lined to some thickness, with a lute composed of the same clay, beaten up with about twice its measure of coarse sand, or rather of glass-house pots in coarse powder.

*Page 66. Glasses gilt on the edges.*

SINCE the publication of the first part of this work, and probably on the principles there pointed out, these glasses have been prepared in England, with as durable gilding as those brought from Bohemia and Thuringia. Of the composition of the varnish I can say no more with certainty, than that oil of turpentine is an ingredient in it. My worthy friend Mr. Ziegler, in an elegant German translation with which he has honoured this work, describes a varnish, with the method of using it, which appeared from his experiments to be the best. Fine transparent amber, reduced to powder, is boiled in a brass vessel having a valve in its cover (see page 368) with as much drying oil as will just cover it: generally in five or six hours the amber is perfectly dissolved. Dilute the solution with four or five times its quantity of oil of turpentine, and let it stand some days



days that all the impurities may settle to the bottom. That the varnish may dry the easier and acquire the more firmness, it is to be ground with a little white lead, or rather with a mixture of white lead and minium. It is to be applied very thin on the glass, and the gold leaf rather blown upon the part, so as it may stick fast, than pressed down with cotton. The glasses may be laid in a warm place, free from dust, till the varnish is fully hardened; after which the gold may be burnished, a piece of smooth paper being laid between the tooth or steel burnisher and the gold. He observes that this gilding is durable and of a fine lustre; and that as the toughest varnishes naturally deserve the preference, the amber varnish above described, promises, in virtue of that quality, to be the best.

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*Page 64. Gilding on the covers of books.*

THE bookbinders dilute the whites of eggs with water, and moisten the part to be gilt three or four times with this liquor: when so far dried as that the gold may not stick without pressing, the part is slightly oiled over before the gold is laid on. Mr. Ziegler, after taking notice of these particulars in a note on the above passage, adds, that for gilding on taffeta or other stuffs, some fine powdered mastich, or white of eggs dried and powdered, is dusted thinly on the stuff; and the gold leaf, first cut to a proper size, is laid on a hot somewhat oiled stamp, and pressed down; with care that none of the powder touch the stamp, which would occasion the gold to stick to it. Our bookbinders, for gilding on rough leather, follow a practice of the same kind, using common resin instead of the mastich or dried whites of eggs: the resin melting only in those parts where the hot stamp is applied and the gold fixed on it, the other parts of the leather remain rough as at first,  
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and on this account only they prefer the dry resin to the liquid glutinous substances.

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*Page 45, 67. Melting of Gold.*

BLACK lead crucibles are said by foreign writers to be accompanied with an inconvenience of rendering the gold brittle and somewhat pale, especially when a new crucible is used for the first time. I had often melted gold in these crucibles myself, and had been told by different workmen that they generally employed this kind, without observing any ill effect from them. On further enquiry among the gold-beaters, whose daily labour is one of the severest trials of the toughness of the gold which they melt, I cannot find that they have any suspicion of its being injured by black lead crucibles, though they now make use of the Hessian or English more frequently than the black lead, on account chiefly of their greater cheapness: one of these workmen informed me that "he had once found gold, which was melted in a black lead crucible, to be brittle, but imagined the brittleness to have proceeded only from want of sufficient heat, for on melting the gold a second time, in the same crucible, it had the proper toughness." The degree of heat is a very material article in the melting of gold: if the gold is but just brought into fusion it proves always brittle, a pretty considerable increase of the fire beyond this point being requisite for giving it full malleability, or for procuring a perfect solution, and an uniform mixture and cohesion of its parts: and when this necessary fluidity has been obtained, the pouring of the metal into a cold mould will render it as brittle as if the heat had been insufficient at first. It is probable that the case is the same in all the other metals, though in no one, perhaps, so eminently as in gold: and we may hence account  
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for the brittleness, which gold, after fusion, is frequently found to have contracted, and which has commonly been ascribed to other causes. I have already taken notice, (page 69) that the general opinion among the chemical writers, of gold being made brittle by a piece of charcoal falling on it in fusion, appeared to be a mistake, and I have since found the same observation made by Mr. Scheffer, in an excellent paper on the parting of metals printed in the Swedish transactions: he says that in the royal mint of Stockholm, the gold is always covered with charcoal in melting, and yet retains the full malleability which it had before.

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*Page 82. Fusibility of mixtures of gold and copper.*

IT has been affirmed, that though mixtures of gold and copper melt easier than gold itself, inasmuch as to serve as a solder for it; yet this does not proceed from any increase of fusibility occasioned by the mixture of the two metals with one another, but merely from copper being more fusible than gold, so that the more copper the mixture contains, the easier it ought to melt. Admitting however that copper does melt easier than gold, which by no means appears to be the case, an increase of fusibility would still follow; for a mixture of gold and copper is a solder for fine copper as well as for fine gold.

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*Page 89. Calcination, &c. of tin with gold.*

THE experiment in which a mixture of gold and tin, calcined to an ash grey colour, is said to have melted with ease into a yellow glass with a regulus at the bottom, I have now tried, but without observing any appearance of vitrification --- 1200 assay weights of fine gold, and 1800  
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of pure tin, being melted together, the mixt was of a white colour without the least yellowness, rough on the surface, tolerably bright underneath, easy to break, of a broad leafy texture like the best regulus of antimony, in weight 2981. Beaten into powder and calcined under a muffle, with a moderate heat, for five hours, it appeared of a light grey colour, and weighed 3283; so that it had gained in the calcination above a tenth part of the weight of the mixt, or between a fifth and a sixth part of that of the tin. The calx was put into an assay crucible, which was inclosed in a larger, and urged with a strong fire for two hours: the cover of the outer crucible, made of Sturbridge clay, remained sound; that of the inner one, made of clay and chalk, melted entirely, and lined the inside of the crucible with an opaque dark-coloured glass. The powder, at the bottom, continued unmelted, and to the naked eye looked nearly of the same appearance as at first, but on viewing it with a magnifying glass, several distinct particles of gold were observed in it. A little of the powder was mixed with about ten times its quantity of powdered flint glass, and exposed to a strong fire in a wind furnace for several hours: the glass proved nearly transparent, uncoloured, a little cloudy, with grains of gold at the bottom.

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*Page 114. Gold with sal microcosmicus.*

Mr. POTT, in a curious dissertation on this remarkable salt of urine, gives some experiments which seem to shew that this salt has little or no action on gold. Ground with gold leaf, and then melted with a blow pipe on a coal, it forms a pearl-like mass, which in the air becomes a transparent slime or jelly: this melts again into the same appearance as before, and on continuing the fusion, the gold separates and rises to the surface in form of a massive leaf,

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the salt remaining whitish. When the salt was melted in a crucible with equal its weight, or a third of its weight, of gold or aurum fulminans, it received no purple or rose colour, and did not appear to take up any part of the gold. Ground with gold leaf, and exposed to the focus of a burning-glass about a foot in diameter, it smoked, frothed, and flowed long, but at length the gold rose up to the surface, leaving the salt clear. One part of the purple calx of gold, precipitated from aqua regia by tin, being mixed with ten parts of the salt, and melted in a crucible with a strong fire; most of the salt rose over the crucible, leaving a brownish glass, and the gold revived into grains. One part of a calx of gold made with quicksilver, and ten of the salt, melted in a strong fire, gave likewise a yellow-brown glass, and the gold was found revived. One part of gold, two parts of sal ammoniac, and eight parts of the microcosmic salt, being melted together, the salt run all through the crucible, the gold remaining in grains.

Solution of gold in aqua regis is precipitated by solution of the microcosmic salt, provided the aqua regis is fully saturated with the gold, and the microcosmic solution added in sufficient quantity. If the mixture of the two solutions be poured upon compositions for glass, the whole boiled down to dryness, then well ground together, and brought into fusion, the gold either wholly disappears, or hardly a footstep of it is to be seen. A composition of three parts of powdered flint, two parts of saltpetre, and one part of calcined borax, being treated in this manner with the mixt solutions; a blue sandiver, almost like turcois, was found on the top of the melted matter, and a pure blue glass underneath. With regard to the blue colour, which may seem pretty extraordinary, the author observes that some variation may happen from the degree of fire, and that the common ruby glass, when in giving

it colour by the flame of wood it is kept too long in a strong heat, changes to an amethyst blue.

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*Page 114. Gold plates for enamelling.*

THAT a certain mixture of alloy is necessary in the gold plates designed for being enamelled on, I have related on the authority of a writer in the French *Encyclopedie*; who says the gold must be of the fineness of twenty-two carats at most, that if finer it will not have strength enough, and that if coarser it will melt. I am told by an experienced artist that this is a mistake; that ducat gold is generally used, whose fineness appears to be from  $23\frac{1}{2}$  to  $23\frac{3}{4}$  carats; and that the finest gold is for this use the best, unless where some parts of the gold are left bare and afterwards polished, as is often done in watch cases, snuff boxes, &c. for which purposes a mixture of alloy is necessary; that silver is preferred as an alloy to copper, the latter disposing the plates to tarnish and turn green; and that the plates are strengthened, by covering them on the back sides with enamel. Thus much is certain, that the finer the gold, the more soft and flexible; and the coarser, the more fusible it proves.

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*Page 121, 123. Touchstone --- not of the marble kind.*

Mr. POTT also has taken notice, that the touchstone is not of the marble kind; and that black marbles, how well soever they may answer for receiving a coloured stroke from metals, are unfit for the use of touchstones, on account of their being dissolved by aquafortis. He makes the touchstone a clayey slate, partaking of iron; and finds, that in a strong fire, like many other ferrugineous clayey minerals, it melts perfectly into a blackish brown slag, and that

that a small quantity of it, mixed with vitreous compositions, gives them a notable green tinge. He observes that the imperfection of flints, &c. for the use of touchstones, consists in their hardness, which occasions them to give too great brightness to the metalline stroke, so that its colour, and consequently the proportion of alloy, cannot be exactly judged of.

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*Page 172, &c. Cassius's precipitate --- Ruby glass.*

CASSIUS does not appear, from his treatise *de auro*, to have been the discoverer either of the precipitation by tin, or of the tinging of glass by the precipitate. He describes the preparation of the precipitate, and slightly mentions its use in this intention; but gives no account of the manner of employing it, nor any practical hint in regard to the operation, except that in speaking of the smallness of the parts of gold, he says that one dram of gold duly prepared will tinge ten pounds of glass.

A process for making the ruby glass has been communicated to me by an artist, who says he was assured it came from Kunkel, and that he had found it a good one for enamelled colour, but had never tried it for glass. The gold is directed to be dissolved in a mixture of one part of spirit of salt and three of aquafortis; and the tin, in a mixture of one part of the former of these acids with two of the latter. The solution of gold being properly diluted with water, the due proportion of which is to be found by trials made on a small quantity as mentioned in page 176, the solution of tin is added, and the mixture suffered to stand till the purple matter has settled to the bottom. The colourless liquor is then poured off; and the purple sediment, while moist and not very thick, is thoroughly mixed with powdered flint or sand: this mixture is well ground

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with powdered nitre, tartar, borax, and arsenic, and the compound melted with a suitable fire. The proportions of the ingredients are, 2560 parts of sand, 384 of nitre, 240 of tartar, 240 of borax, 28 of arsenic, 5 of tin, and 5 of gold.

I have not yet had an opportunity of trying this process, but am convinced, that the mixing of the precipitate with the sand, &c. in a moist state is a very material circumstance, if not the principal one upon which the success of the operation depends. Perhaps the most certain way would be, not to wait for any precipitation at all, but to moisten the powders with the purple liquor, grinding them well together, in a moderate warmth, till dry, and if necessary, repeating the humectation. Mr. Potts experiments with the microcosmic salt, mentioned in page 619, confirm the utility of this method of mixture.

*Page 185. Quantity of gold collected in rivers.*

IN a paper drawn up by Mr. Guettard, from the observations of Mr. Paillès, and published in the volume of the French memoirs for the year 1761, the gold found in rivers is reckoned an object of more importance than it has been usually represented. It is said that the mint of Toulouse received commonly every year two hundred *marcs*, or one hundred pounds weight, of gold collected from the Ariège, Garonne, and Salat; and that since the year 1750, twelve pounds have been carried into the *bureau* of Pamiers, though this *bureau* comprehends at most an extent of only two leagues round, and though the whole of the gold is not sent thither, strangers and hawkers buying it up every day.



*Page 186. Source of the gold found in rivers.*

IT has been generally thought that the particles of gold, found among the sands of rivers, have been torn off by the violence of the stream, in passing over some rich beds or veins. The observations of Mr. Pailhès, in the memoir before mentioned, seem to prove, that the gold is not confined to any particular spot, but diffeminated, though very sparingly, through all the adjacent earths; and that the particles found in the rivers proceed from part of the banks washed down by floods and rains, the lighter earth being carried away by the current, while the gold particles, with the ponderous black sands and flints, settle to the bottom. The author relates, that those who employ themselves in collecting the gold, sometimes anticipate the effect of the floods, by privately cutting down or undermining the banks, that the gold particles may be separated, which occasions frequent law-suits between them and the proprietors of the grounds: That in the town of Pamiers, situated on one of the celebrated auriferous rivers, Ariège, on digging for wells or foundations of buildings, the earth thrown up is always found to contain particles of gold: That he has discovered abundance of auriferous tracts in other parts of the territory of Foix, infomuch that he imagines it would even be more difficult to procure water for the washing than to find the gold: and that besides the gold met with in detached particles, the flints that accompany them contain also gold, which might be separated to advantage by stamping and washing. A quantity of these flints was sent by Mr. Pailhès to the academy, but in the assays made of them they appeared to be merely ferrugineous, yielding near half their weight of iron, without any mark of gold.

*Page 221. Gold coloured metal.*

THE celebrated Mr. Pott, in a German letter to Von Justi printed in 1760, affirms that tombac, or a gold coloured metal, may be made from a mixture of copper and tin; and in a further discussion of Von Justis objections, printed in 1762, he gives the particular composition of this metal. "Take one half-ounce of tin ashes, and four half-ounces of copper: melt them well together, in a close luted crucible, with a strong fire. Or take one half-ounce of the purest tin cut in pieces, and sixteen half-ounces of pure copper beaten into thin plates: lay the tin between the copper plates, lute the crucible close, and melt with a strong fire."

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*Page 224. Gold coloured varnish.*

THE composition of a gold coloured varnish, used by the English artists for brass and silver, was communicated to some of the French academicians, in 1720 by Mr. Scarlet, and in 1738 by Mr. Graham, and has lately been published in the volume of the French memoirs for 1761. Though I do not apprehend that this varnish is anywise superiour to that described in the page above referred to, I shall here insert it for the satisfaction of the reader. "Take two ounces of gum lac, two ounces of yellow amber, forty grains of dragons blood in tears, half a dram of saffron, and forty ounces of good spirit of wine: infuse and digest in the usual manner, and then strain through a linen cloth. The piece to be varnished must be heated before the liquid is applied: it receives from the varnish a gold colour, little different from that of the mercurial gilding, and may be cleaned, when sullied, with warm water." It may be presumed that the amber is of no great use

use in the composition, this concrete being very sparingly dissolved by the spirit.

As the spirit for varnishes ought to be freed as much as possible from its phlegm or watery part, and as this is most conveniently effected by means of fixt alkaline salts, I accordingly directed the spirit to be shaken with so much alkali as should be sufficient to imbibe the phlegm. In Meyers very ingenious German treatise on quicklime, published in 1764, it is observed, that spirit rectified with these salts is unfit for varnishes, particularly for such as are to be applied on gilt works, the spirit taking up a part of the salt, which darkens the colour, and prevents the speedy drying of the varnish. This observation seems to relate to spirits that have been dephlegmated, not simply by suffering them to stand some hours on the alkali in the cold, and occasionally shaking the vessel, but by the application of a considerable heat; in which last case the spirit is known to take up a small portion of the alkaline salt, but that it dissolves any in the first is not so clear. If, however, the spirit should in either way have received an alkaline impregnation, it may easily be purified by means of a little alum well dried and powdered, the alkali being absorbed by the acid of the alum, and forming therewith a compound not combinable with vinous spirits. Some persons, when a perfectly pure spirit is required, first dephlegmate it with alkaline salts, and afterwards purify it from such part of the alkali as remains in it, by a fresh distillation from a quantity of alum: perhaps simple infusion and agitation with the alum would be as effectual, at least for the purpose of making varnishes, as the more troublesome process of distillation.

*Gold coloured Glafs, with metallic fubftances.*

PRECIPITATES of filver, baked on glafs, ftain it yellow, and likewise give a yellow colour on being mixed and melted with forty or fifty times their weight of vitreous compositions: the precipitate from aquafortis by fixt alcali feems to anfwer beft. I have likewise obtained yellow glaffes with certain preparations of iron, particularly with Pruffian blue. But neither with filver nor with iron does the colour fucceed constantly, or approach to the high yellow of gold.

The neareft imitations I have obtained of the colour of gold in glafs, were produced with antimony and lead. A quantity of crude antimony in fine powder was calcined by a little at a time in a flat iron pan, with care to prevent as much as poffible its running into lumps, by ufing a very gradual fire, and keeping it constantly ftirring, till at length, when brought to a full red heat, it neither foftened nor emitted any fumes. The afh coloured calx, weighing little more than half of the crude antimony, was put into a crucible, and urged with a ftong fire in a blaft furnace: it melted into a glafs, dark coloured and opaque in pieces of any confiderable thicknefs, and of a tranfparent yellow when drawn out thin.

Some of this glafs, reduced to powder, was mixed and melted with four times, three times, and twice its weight of powdered flint glafs: the glafs resulting from the firft mixture was of a tranfparent pale yellow, from the fecond deeper, and from the third of a pretty deep yellow, without any mixture of greenifh or brown. Equal parts of the glafs of antimony, of flint calcined and powdered, and of minium, formed a glafs of a high yellow, and with two parts of glafs of antimony, two of minium, and three of powdered flint, the colour approached ftill more to that of gold.

gold. All these compositions were bright and transparent, without any scum on the surface or regulus at the bottom. The last exhibited a multitude of small sparkles interspersed through its whole substance, which gave it a beautiful appearance in the mass, though in the lapidaries hands they were found to be imperfections, arising from air bubbles. It is pretty remarkable, that in several repetitions of this experiment, in a glasshouse furnace as well as in my own laboratory, the product was always full of these brilliant specks.

Glass of lead and glass of antimony make likewise a gold coloured glazing for porcelain and earthen ware. The finest gold glazing is said to be made with an addition of silver. A glass of lead is prepared by melting minium or litharge with a third or a fourth part of its weight of powdered flint. This yellow glass, reduced into fine powder, is either sprinkled on the porcelain made red hot, or mixed with beer or other glutinous liquids to a due consistence, and applied with a pencil: the ware is then placed in the furnace, under a muffle, till the glass begins to melt, which is known by its glistening; after which, while warm from the fire, it is moistened with a diluted solution of silver, and baked again. Or the powdered glass of lead is moistened with the silver solution, then melted, and the glazing of the ware finished in one process, by applying on it this compound glass. After the baking, the glazed vessels, while still red hot, are held over the smoke of burning straw, &c.

*Gold coloured glasses without metallic substances.*

THERE are sundry earthy bodies, as chalk and gypsum, which make a yellow colour in glass, especially when the vitrification is procured with borax or alkaline salts. These glasses however have generally more or less of a

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green tinge, and never, so far as I have observed; a gold yellow.

Neri directs, for a gold yellow colour, one part of red tartar, and the same quantity of manganese, to be mixed with a hundred parts of fritt or the composition for glasses.

Kunkel, in his experimental remarks on Neri, says that this process gave him more trouble than any other in the book; that the proportions are quite faulty; that the quantity of manganese is too much for the tartar, and the tartar too little for the fritt; that one part, or one and a quarter of manganese, is sufficient for a hundred of fritt, but that six parts of tartar are hardly enough, especially unless the tartar is of a dark red colour almost blackish; and that he found it expedient to add to the tartar about a fourth of its weight of powdered charcoal. He takes notice that the composition swells up greatly in melting; that if the glass be much stirred with the iron, as is customary for other kinds of glass, it will rise up so as to run over the pot, though at first no more than half full; and that therefore it must be left unstirred, and worked as it stands in fusion. Speaking afterwards of a yellow enamel tinged with the same materials, he adds, that the colour must be carefully washed, too long a continuance of fire destroying it.

My ingenious friend Mr. Samuel More, in repeating and varying this process with a view to render the colour more perfect, found that the manganese is entirely inessential to the gold colour, and that the tartar is no otherwise of use, than in virtue of the coaly matter to which it is in part reduced by the fire. Different kinds of coals, as that of tartar, common charcoal, soot, dried blood, &c. on being melted with colourless fritts or glasses, gave always pale yellow, dark yellow, reddish, brownish, or blackish colours, according as the inflammable matter was in smaller

or larger proportion ; the phlogiston, or inflammable part of the coal, seeming to be the direct tinging substance. When the phlogistic matter was thus diffused through glafs, he did not find it to be affected by continued strong fire, any more than charcoal is when excluded from the air : though some pots of the coloured glafs stood for a fortnight in the glafs-house furnace, they still retained their colour ; nor did the most intense fire of a lamp alter it in the least. How fixt the colour when once united with the glafs is, we may judge from the indestructibility, by very strong fire in open vessels, even of the superficial browns and blacks which charcoal and soot communicate to glafs in its conversion into porcelain : see page 242.

Mr. Pott, in his *neue wichtige physikalisch-chemische materien*, &c. printed in 1762, observes also that common coals give a yellow colour to glafs ; and that even by cementation, provided the heat is not sufficient to change it towards porcelain, they stain it of the same colour. He says that different coaly matters differ in their tinging power ; that caput mortuum of soot, and lamp black, answer better than common charcoal, and that he has known some persons employ the coal of indigo : That the sparkling coal, which remains in the retort after the rectification of the thick empyreumatic animal oils, is one of the most active of these kinds of preparations, being as it were the heavier part of the inflammable substance of the oil, and very rich in colour : That this preparation, powdered and then again burnt a little in a close vessel, is excellent for tinging glafs, and gives yellow, brown, reddish or blackish colours according to its quantity : That the fritt must not be very hard of fusion, for if it is, the strong fire will destroy the colouring substance before the glafs melts ; and that he has found the following compositions to be nearly the best, viz. sand 2 parts, alkali 3 parts ; or sand 2, al-

M m m m 2

cali

cali 3, calcined borax 1; or sand 2, alcali 2, calcined borax 1: That though saltpetre is hardly, or very sparingly, used for yellow glasses, as it too much volatilizes the colouring substance; yet here for the most part a certain proportion of it, which proportion will be easily found by trial, is very necessary, for without it the concentrated colouring matter is apt to make the glass too dark, and even of an opaque pitchy blackness.

That there is any material diversity in the effects of different coals, may be justly questioned; for Mr. More obtained, with common charcoal, the same colours, as with the coals which are here supposed to be of greater excellence and activity: it is probable, that the only difference consists in their containing different quantities of the inflammable matter, so that a little more shall be required of one kind than of another, for producing the same degree of colour in the glass. Nor does the softness or fusibility of the fritt appear to be anywise necessary, for my friend informs me that he has tinged, with coal, glasses which were so hard of fusion, that the glassmen could not work them, whereas the above compositions are all rather too soft to be serviceable in the large way.

*Page 233. Conversion of green glass into porcelain.*

SOME have complained, that on repeating these experiments, the change did not succeed; and further enquiry has shewn, that some sorts of green glass are unfit for this operation. Green glass has been chiefly made of vegetable ashes and sand, brought into fusion together by a strong fire: with this kind, which is the green glass common about London, the experiments succeed in the manner described. In some parts of this kingdom, instead of vegetable ashes, the vitrification of the sand has been procured,  
princi-



principally by means of another ingredient, the slags of the iron furnaces; and glass of this composition is found not to be convertible into porcelain. The failure of this kind of glass serves to confirm the general results drawn from the former experiments; that earthy and metallic glasses made without saline matter, are not susceptible of this change; and that the change depends on the saline substance contained in the vegetable ashes.

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*Page 314. Machines for blowing air by a fall of water.*

I HAVE received an account, from a worthy correspondent in Swisserland, of a machine which he has constructed for a smelting furnace according to the foregoing directions: he says, it has so much the advantage of all other kinds of bellows, that it deserves to be introduced universally wherever the situation of the place will permit. The only inconvenience he finds in it is, that the cullender and gratings are liable to be stopp'd up by leaves, &c. With regard to the cullender, the obstruction may be obviated by enlarging the holes. The gratings ought to be of a large surface: the wire grating in the cistern on the top may be a cylinder nearly as large as the cistern will receive, for if it is no more than sufficient to cover the mouth of the pipe, it will doubtless be soon choak'd up: when so much of the cylinder becomes stopp'd, that the water has no longer a free passage through, it may be lifted up and cleaned, another being placed in the room of it, without the trouble of turning off the water, or interrupting the going of the machine. The gratings here can be liable to no other inconveniences, than those which are common in other water machines, mills, aqueducts, &c.

Some further improvements have occurred in the construction of these machines, by which they may be made  
effectual

effectual in cases where the quantity or fall of water would otherwise be insufficient.

*Of constructing blowing machines with falls of water of great height.*

WHERE the height of the fall is great, the quantity of water is usually small; and in all the ways of application that have hitherto been contrived, the height will by no means make amends for the deficiency in quantity.

In the common construction of these machines, where the upper pipe or funnel is no more than three, four, or five feet high; though the fall should be such as to admit of the lower pipe being thirty or forty feet or more, it does not appear that any material advantage could result from such a height. For, as the air is admitted into the water only at the top of this long pipe, it cannot, I think, be supposed, that the quantity admitted will be the greater for the length of the passage under the place of its admission. Water indeed has been found by Mariotte to run faster, through an upright long pipe, than through a short one: a quantity of water which was forty-five seconds in running through a pipe three feet long, was discharged in thirty-seven seconds, or near a sixth part less time, through a pipe of the same bore and a double length; so that as more water passes successively through the long pipe than through a short one, in equal times, more air also must be carried down by it. But in the case which we are here considering, no benefit can be expected on this principle; for as the supply of water is supposed to be limited, the bore of the pipe must necessarily be made less, in proportion to the increase which its length may produce in the velocity. If the lower pipe is of such height, that the watery column it contains may sufficiently resist the force of the compressed air in the air-vessel, it should seem that any

any further addition to its height could be of no manner of use.

We have seen, in the foregoing part of this essay, that it would be more advisable, in such cases, to shorten the lower pipe, and to lengthen the upper one: by this means the water, acquiring greater velocity at the place of its discharge from the upper pipe into the lower, is enabled to divide or spread more, and thus to receive more air into its interstices. The advantage, thus obtained, does not however increase in so great a proportion as the height does. From an experiment related in page 310 it appears, that by increasing the height four-fold, the effect was not increased three-fold; and this even in small heights, where the effect is much more influenced by a variation of the height than in great ones.

The observations already mentioned point out means of availing ourselves more advantageously of high falls; so as to produce always with certainty, from a fall of a double or treble height, a double or treble effect if the quantity of water be the same; or an equal effect, with one half or one third the quantity of water.

Experiments have convinced me, that a fall of fourteen feet is more than sufficient for compressing the air to such a degree, as to be able to sustain the gage at the height of four feet; or to raise, on an opening of a square inch, a weight of about a pound and three-quarters avoirdupois, or above two pounds troy; a compressure, which is apprehended to be as great as there will in general be occasion for. Where we have plenty of water, with such a fall, we can drive in air, with this force, in any quantity: for if one machine, with a certain portion of the stream, produces a continued blast of this strength through a pipe of a certain bore, as an inch or three-quarters of an inch; it is evident; that the quantity of air may be doubled, trebled, &c.

at pleasure, without diminishing the compressure or force of the blast, by adding another and another machine, till all the stream is employed. It is plain, in like manner, that the same advantage may be received from high falls, by placing one machine over another; that after the water has performed its office in falling through one machine, it is still capable of exerting the same action in another and another machine, so long as equal spaces remain for it to fall through; so that the total effect must be the same, as if a quantity of water, sufficient for working all the machines, came at first in one stream.

A fall thus divided into two machines is represented in the middle of the annexed plate. In the lower machine, whose air-vessel is sunk to a considerable depth in a pit made in the ground, the water is forced up in the pit, on the outside of the vessel, four feet higher than the surface of the water within the vessel, or of the stone on which the water dashes, called by the workmen the dash-board, (see page 287). The air-vessel of the upper machine having an additional part at one side, which performs the same office as the pit, the water is in like manner forced up to the same height in this outer part; which outer vessel serving as a reservoir for the machine under it, the water begins to act in this lower machine four feet higher up than the dash-board of the first. Whatever number of machines the fall will admit of, the case is the same in them all: though in each of them the water falls eighteen feet, yet as it is pressed up again four feet for the succeeding machine, one machine takes up but fourteen feet of the real fall.

The outer vessel, and its communication with the air-vessel, may be conveniently formed by an upright partition in the air-vessel itself, not reaching quite to the bottom. The outer division may be open at top, and needs not be  
so

so high as the close air-vessel; it is sufficient if it reaches a little more than four feet above the level of the dashboard, the water, which it is designed to receive, not rising higher than this. In other respects, the structure of these machines agrees entirely with that of the single ones already described. It must be observed only that the cullenders of the lower machines should be, as nearly as possible, of the same dimensions with those of the upper ones. For if they are of smaller bores, they will not admit of all the water which passes through the upper ones, so that part of it must run to waste: if they are larger, the water will pass off too fast, without producing its due effect. The regulators, described in page 312, are here particularly useful, affording ready means of increasing or diminishing the apertures occasionally while the machines are at work.

*Of blowing machines with low falls of water.*

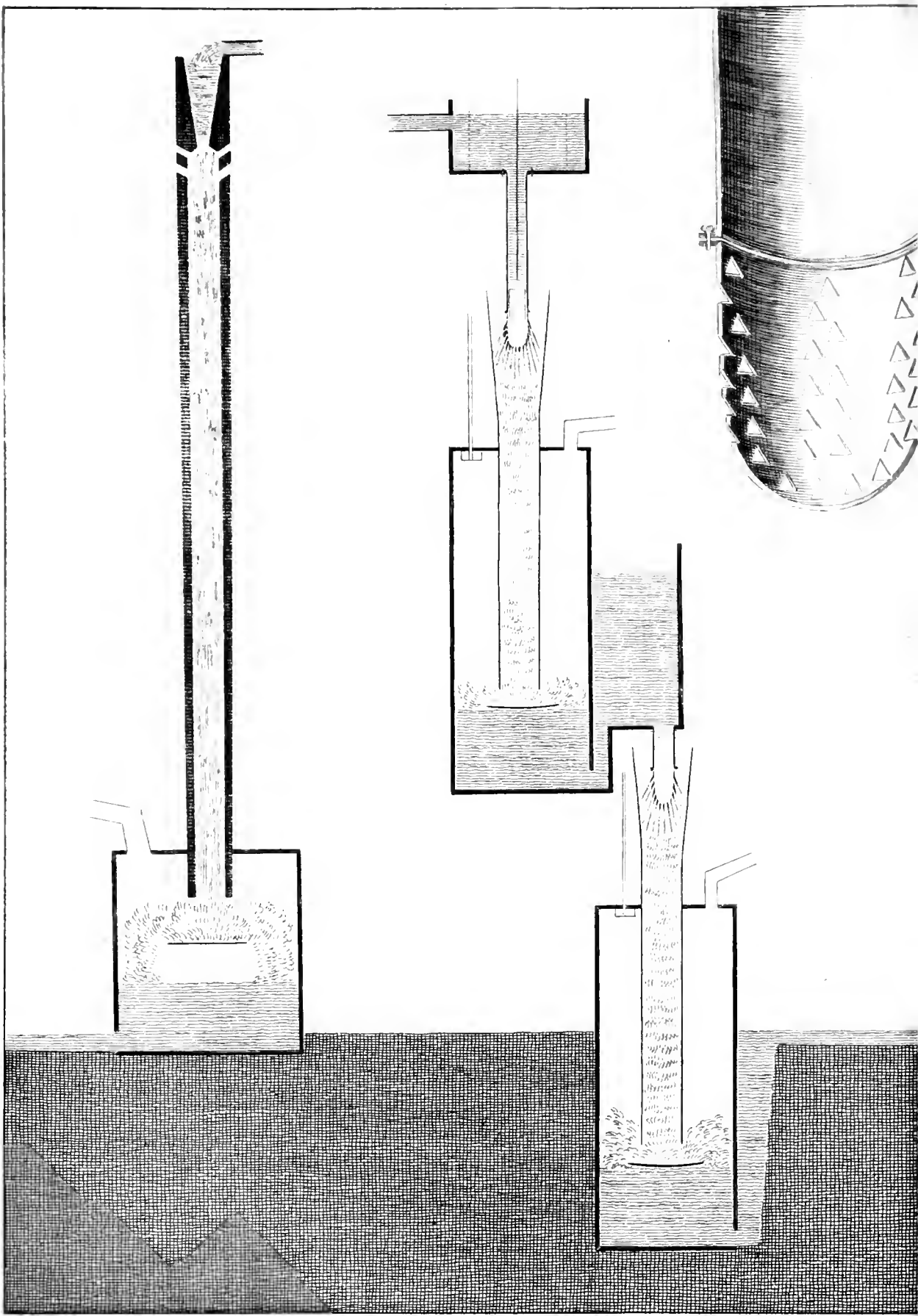
THE dimensions hitherto given are such as appear the most advantageous. Much lower falls, however, than those which the foregoing machines are calculated for, as ten, eight, or perhaps seven feet, may be made to afford a strong blast. To produce such a compression of the air in the air-vessel, as to raise the gage four feet, a fall of about six feet is necessary for the lower pipe. If the upper pipe is only about a foot and a half or two feet, the water, when divided by means of the cullender, will carry down a certain quantity of air; and though the quantity, from an equal stream of water, will not be so great as when the fall is higher, yet, as there are in many parts of the kingdom, large bodies of water running with such a descent, the deficiency may be compensated, as already taken notice, by enlarging or multiplying the machines.

For many purposes still less falls will suffice. The smiths bellows, as we have formerly seen, raises the gage only about fourteen inches; and such a compressure, it is presumed, may be gained from a fall of five feet or less. Small falls may be applied also to another purpose, of no little importance, the ventilation of mines and coal-pits, or the driving in of fresh air, in the room of that, which the mineral vapours have rendered unwholesome or pernicious.

In all these machines it must be observed, that the height of the column of water, falling through the pipe, determines, not the actual force of the blast, but the greatest force which can be given it in that machine; that the height of the gage is always the measure of the actual force; that this force depends on the width of the pipe through which the air is discharged from the air-vessel, and may be diminished, or increased in any degree up to the greatest that the column of water can resist, by widening or narrowing the aperture of the pipe; that different machines will give blasts of equal force through pipes of greater or less width, according to the greater or less quantity of air which the water carries down with it; and that therefore the size of the blast-pipe must be adjusted by trial for each particular machine.

The distance of the dash-board under the pipe may likewise admit of some variation, and require to be regulated according to the size of the pipe. In some of the common machines, this distance is three or four feet or more; but so large a space is apparently a disadvantage; for so much of it, as is more than sufficient for the free passing off of the water, is entirely useless, being, in effect, so much taken off from the height of the fall. The distance of six inches, laid down in the foregoing machines, is designed for a circular pipe of twelve inches diameter; in which case, the area, by which the water is discharged  
all







all round, is just double to the area of the pipe, and consequently more than large enough for letting the water off without impediment.

*Explanation of the Plate.*

THE two blowing machines, represented on the plate, are both drawn to one scale, that the eye may judge more readily of their comparative heights and dimensions. The supports of the reservoirs, &c. are not expressed, that the essential parts may be the more distinct.

The machine on the left hand is that of Dauphiny, described in page 274, with a fall of about thirty feet. The other is a natural fall of twenty-eight feet, formed into two artificial ones of eighteen feet each; see page 310 and 634. This double machine, though somewhat lower than the other, may be presumed to have twice its effect, in virtue of the division; besides the advantage of the more free admission of air, and the spreading of the stream through a pipe of a much larger bore, by which it is enabled to carry down in its interstices a much greater quantity of air. The dotted lines, in the upper reservoir, represent a cylindrical grating of iron wire, to keep back weeds, &c. The division of the air-vessel, and the course of the water from the upper machine to the lower, are apparent from the figure.

On the right hand is a perspective view of the cullender, screwed to the upper pipe, drawn to a larger scale, to shew the disposition of the holes. The holes may be made wider than formerly proposed, as an inch each side, to prevent any danger of their being choaked up.

*Page 321. Black Diamond.*

I HAVE been favoured with a sight of this stone, and am assured it is a true diamond. At a distance, it looks uniformly

N u n n e

formly

formly black; but on clofer examination, it appears in fome parts tranfparent, and in others charged with foulnefs, on which the black hue depends.

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*Page 359. Indian ink from lamp-black and glue.*

SINCE the experiments on the compofition of Indian ink were made, I have met with an account in Du Haldes hiftory of China, which feems to confirm them. He gives three receipts for the preparation of this commodity, two taken from Chinefe books, and the third communicated by a native to one of the miffionaries. The colouring material in all of them is lamp-black, to which is added, in one, a quantity of horfe-chefnut burnt till the fmoke ceafes: he does not determine whether the wood or the fruit of the horfe-chefnut tree is meant, but adds, from the Chinefe author, that if ufed in over-proportion, it inclines the black colour to a violet. The conglutinating matter, in one of the prefcriptions, is a thin fize of neats leather; in another, a folution of gum tragacanth; and in the other, a mixture of fize with a decoction of certain vegetables to us unknown. The firft, viz. lamp-black and fize, which is that from verbal communication, is the very compofition which our experiments pointed out. As to gum tragacanth, it certainly is not the conglutinating ingredient in any of the famples of Indian ink that have come under my examination, the vegetable gum not putrefying with water as the Indian ink does: if gum was really made ufe of, gum tragacanth fhould feem the moft unfit for the purpofe, on account of its difficult and imperfect folution in water. The vegetable decoctions or infufions I cannot apprehend to be of any manner of ufe where fize is employed, unlefs it fhould be to give a fcent to the compofition, in which intention, mufk and other perfumes

perfumes are said to be frequently mixed with it. The author observes that the Chinese have inks of different goodness and price; that the most essential difference proceeds from the quality of the lamp-black; and that the best lamp-black is the soot of oil, which is burnt in lamps, in apartments fitted up for this purpose. The Chinese, according to his account, imagine the differences in the soot of different oils, &c. to be much greater than the experiments related in page 342 give room to believe they are.

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*Page 369. Black varnish for metals.*

THE workmen frequently employ for this purpose, as I am informed, a mixture of lamp-black with the scum-mings, &c. of different oil paints: the mixture is applied with a pencil, and the piece afterwards baked in an oven, with a heat somewhat greater than is used for the papier machè. Naples yellow, a superfluous ingredient in the black varnish, is the basis of the dark brown which we see on some iron snuff-boxes, this pigment changing to a brown in baking with the varnish.

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*Page 596. Separation of the alkali of sea salt.*

1. *Purification of sea salt.*

PURE marine salt is a combination of the mineral alkaline salt with marine acid: but all the common sorts of this salt have a mixture of one or more saline matters of a different composition, their basis, instead of an alkaline salt, being an earth; which earth is generally the same with that called magnesia, though sometimes, perhaps, it may be of the calcareous kind.

1. These

1. These salts with an earthy basis are discovered, by dissolving the marine salt in water, and dropping in a solution of any alkaline salt. The earth, of whatever kind it be, precipitates; the acid, which held it dissolved, quitting it, to unite with the superadded alkali; so that by continuing to drop in more of the alkaline solution, till it ceases to occasion any precipitation or cloudiness, we produce in the liquor, instead of the salt with an earthy basis, a true neutral salt with an alkaline basis.

2. In some sorts of marine salt, the acid united with the earth is the vitriolic. This may be known, by dropping, into a solution of the salt, a solution of chalk, or other calcareous earth, made in the nitrous, marine, or vegetable acids. The vitriolic acid quits the earth which it was before combined with, and joins itself to the calcareous earth, forming therewith a selenitic concrete, not dissoluble or exceeding sparingly, and which therefore settles to the bottom in a powdery form; so that by continuing to drop in a due quantity of the calcareous solution, all the vitriolic acid may be separated with the calcareous earth, while the magnesia, now combined with the acid in which the calcareous earth was before dissolved, remains in the liquor along with the marine salt.

3. There is another method in which we can separate the vitriolic acid, and this without communicating any foreign impregnation to the liquor. Add to the solution of the marine salt, some strong lime-water: the vitriolic acid unites and precipitates with the lime; and the magnesia, thus deprived of its acid solvent, precipitates also. Though this simple process effectually purifies the salt from the combination of vitriolic acid and magnesia (commonly called bitter salt, or bittern) it does not answer so well, for merely distinguishing that acid, as the foregoing method; lime-water producing a turbidness and precipitation in many liquors which contain no vitriolic acid.

4. In many kinds of marine salt, the heterogeneous earth is united with the true marine acid: we may always judge that this is the case, when the method of trial No. 1 discovers that the salt contains an earth, and when the calcareous solution No. 2, by producing no cloudiness, shews that the acid is not the vitriolic. The combination of either magnesia or calcareous earth, with the marine acid, or with the nitrous acid if such an acid should ever exist in marine salt, I know of no other means of separating, than decomposing it by alcalies as in No. 1, or careful crystallization.

The combination of earth with marine acid I have found to be by much the most frequent and most considerable admixture in the common marine salts used among us at table. This compound liquefies easily in the air, a well known imperfection in the common sorts of marine salt; and on this disposition to liquefy depends its being in great measure separable by crystallization. The bay salts, crystallized by the slow evaporation produced by the suns heat, have much less of this deliquible salt, and hence are much less subject to grow moist in the air, than those prepared by the hasty boiling down of the brine; though they generally have a pretty large admixture of the bitter salt, which crystallizes as perfectly, though not so soon, as the marine salt itself.

On this bitter salt probably depends a property of the common marine salts, which has given occasion to some mistakes in regard to their composition. When common salt has been melted in the fire, it afterwards deliquesces very speedily in the air, though before it was of such a kind as to be little disposed to grow moist. This does not seem to proceed from the salt being rendered alkaline, or losing any of its acid, but from such a transposition of its acids as we find to happen when artificial mixtures of the same

same ingredients are treated in the same manner : the vitriolic acid of the bitter salt, loosened from its earth by the heat, unites with so much as it can saturate of the alkali of the marine salt ; and the marine acid, disengaged by the other from this part of the alkali, unites with the magnesia which the vitriolic acid has forsaken, forming therewith, instead of the crystallizable bitter salt, the very deliquible compound above mentioned. It has been found indeed, that common salt gives out a portion of marine acid, when solutions of it are hastily boiled down, or when the dry salt is exposed to strong fire : but the compound of earth and marine acid parts with some of its acid in the same circumstances, and Mr. Baumè has shewn, in his *manuel de chymie*, that marine salt, purified from that compound, does not.

The purification of marine salt from its earth, by the addition of alkaline salts, No. 1, how useful soever it may be to the saltboiler, must never be had recourse to in the present intention, unless we have an alkali exactly the same with the marine alkali itself ; for by whatever means we can disjoin the marine alkali from its acid, we shall disjoin along with it this extraneous alkali. Nor indeed is such a purification anywise wanted here ; for in separating the acid from the alkali, we separate it from the earth also, and the alkali is afterwards purified from this earth, along with the other earthy matter which it has contracted in the operation, by solution in water. For the two first processes of the following article, it is sufficient if the salt is well purified from vitriolic acid ; and for the third, even that purification is unnecessary.

## 2. Preparation of cubic nitre.

THE acid of common salt can neither be expelled from its alkali by fire, nor transferred from it, so far as is known,  
to

to any other body. But though we cannot transfer the marine acid from the alkali; we can transfer the alkali, from the marine acid, to the nitrous acid; and from this last acid we can separate the alkali pure. The combination of this alkali with the nitrous acid is called, from the figure which it assumes in crystallization, cubic nitre.

I. Cubic nitre may be prepared, by putting into a glass retort some common salt, pure from vitriolic acid, thoroughly dried over the fire, and reduced to powder; setting the retort, on as much sand as will keep it steady, in an iron pot placed in a proper furnace; pouring in thrice the weight of the salt, of strong smoking spirit of nitre, with care to avoid the fumes; immediately luting on a large receiver, with some water in it to promote the condensation of the fumes; and proceeding to distillation, with a very gradual fire, increased at last so as to make the bottom of the retort red hot. The marine acid, with part of the nitrous, comes over into the receiver: the marine alkali, combined with the rest of the nitrous acid, remains in the retort. The mass of salt is to be dissolved and washed out of the retort with distilled water or pure rain water, the solution filtered, evaporated with a moderate heat till a pellicle begins to appear on the surface, and then set in the cold: the salt shoots into cubical or rather rhomboidal crystals, generally clustered together.

Mr. Marggraf, in a dissertation on the best method of separating the alkaline substance of common salt, found that two parts of smoking spirit of nitre, of such strength as instantly to fire pure oil of cloves, were sufficient for one part of purified common salt; but of the weaker nitrous spirit, called aquafortis, he recommends eight times the weight of the salt. He says the crystals obtained with the smoking spirit (for he does not seem to have actually

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tried

tried the weaker one) were pure cubic nitre, which deflagrated on a burning coal without crackling, and had not the least mixture of common salt. Some have reported, that though a pretty strong spirit of nitre was used in more than double the weight of the salt, the residuum after the distillation consisted chiefly of marine salt unchanged, with only a small proportion of cubic nitre intermixed. On what cause the failure depended, the few experiments I have made on this head do not enable me to judge: perhaps it may be necessary that the nitrous spirit should be very strong, for a concentrated acid may produce decompositions, as well as dissolutions, which the same acid, diluted, is incapable of effecting.

II. Cubic nitre may be obtained also in the process of making silver into luna cornea, which is the most effectual way of purifying silver. Solution of common salt in water being dropt by degrees into a solution of silver made in aquafortis, so long as any cloudiness ensues, the marine acid precipitates with the silver, as the vitriolic did with chalk in No. 2 of the foregoing article, and the remaining liquor is a solution of cubic nitre, blended with the copper which the silver contained. How far this copper may be injurious in the intention for which cubic nitre is here wanted, has not been fully examined.

III. The strong affinity of the vitriolic acid to calcareous earth affords a method of obtaining cubic nitre, more eligible than either of the foregoing. Spirit of salt is commonly prepared by distillation with the vitriolic acid; and in this case, what remains in the retort is a combination of that acid with the alkali of the marine salt. This compound is common in the shops, under the name of *Glaubers salt* or *sal mirabile*. If a saturated solution of sal mirabile be made in water, and a solution of chalk in aquafortis added by degrees so long as it occasions any cloudiness;



cloudiness; the vitriolic acid and the chalk precipitate together, and the nitrous acid and mineral alkali remain in the liquor, which accordingly, on crystallization, yields a true cubic nitre. The solutions ought to be well saturated, that the milkiness, which grows fainter and fainter as we continue to add more of the calcareous solution, may be the better distinguished; and after the cloudiness seems to have entirely ceased, a little more of this last solution may be dropt in, for a small excess in its quantity will be of no inconvenience, but a small deficiency, by leaving part of the sal mirabile undecomposed, will occasion the mineral alkali, for which this process is only preparatory, to be impure, as will appear in the following operation.

### 3. *Separation of the mineral alkali from cubic nitre.*

THE marine alkali being by the above methods combined with the nitrous acid, the acid is to be separated from it by deflagration with inflammable substances. Mix the cubic nitre with one fifth or one sixth of its weight of powdered charcoal, grinding them thoroughly together: the coal of animal substances is preferable to that of vegetables, as the latter will leave, after burning, some small portion of an alkaline salt, of a different nature from that which is here required. Throw the mixture, by a very little at a time, into a large crucible made just red hot, covering the crucible, as speedily and as close as may be, after each injection, to prevent the matter from being dissipated by the strong deflagration which ensues. When the mixture has been all thrown in, and the detonation has ceased, the fire may be augmented, and a pretty strong red heat kept up for half an hour or more, the crucible during this time being left uncovered. The nitrous acid being thus burnt out, there remains in the crucible a blu-

ish-greenish alkaline mass, which is to be purified by solution in distilled water. It dissolves more difficultly than the vegetable alkalies, and on duly evaporating the solution shoots into fine white crystals, which do not liquefy in the air. This last property of the marine alkali tends to confirm the observation already mentioned, that the deliquation of marine salt after fusion does not proceed from a part of the alkali having been divested of its acid.

If the marine salt, used for the preparation of cubic nitre by the first and second processes, contained any salt with an earthy basis, or if the solution of chalk in the third way of preparation was employed in too great quantity, the crystallization of the cubic nitre will in great measure separate those deliquiable compounds; and indeed, without crystallization, as the nitrous acid is dissipated or destroyed in the fire, it will leave with the alkali only the earth, which will be separated, as well as the ashes of the coal, by the dissolution in water. If the cubic nitre contained any marine or vitriolic salt, the marine salt will continue after the deflagration unchanged, and the vitriolic salt will produce with the inflammable matter a sulphureous compound.

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