John Adams Library,

IN THE CUSTODY OF THE
BOSTON PUBLIC LIBRARY.

SHELF Nº
* ADAMS
181.29

John Adams
1796

THE

FIRST PRINCIPLES

OF

CHEMISTRY.

THE

FIRST PRINCIPLES

OF

CHEMISTRY.

BY

WILLIAM NICHOLSON.

THIRD EDITION, REVISED BY THE AUTHOR.

LONDON:

PRINTED FOR G. G. AND J. ROBINSON,

PATERNOSTER-ROW.

M.DCC.XCVI.

3590

[illegible] - 29

TO

HENRY CAVENDISH, ESQ.

F. R. S. AND A. S.

AS AN ACKNOWLEDGMENT

OF

THE NUMEROUS ADVANTAGES

WHICH

THE SCIENCE OF CHEMISTRY

HAS RECEIVED

FROM HIS DISCOVERIES:

THIS TREATISE

IS

RESPECTFULLY INSCRIBED.

PREFACE.

I HAVE ſpared no pains in collecting materials for the Treatiſe I now preſent to the world: I have condenſed thoſe materials into one volume, with more labour than I might have employed in diſtributing them into two or three: and I have printed it on a page unuſually full, at the ſame time that I have revived an ancient and uſeful practice of annexing ſide notes and references; which I believe has fallen into neglect, becauſe it requires great care in the author, uncommon attention in the printer, and adds to the expences incurred by the publiſher.

If the work ſhould not therefore prove to be ſo uſeful as my intention deſigned it, the defects will have ariſen chiefly from a want of that ability, which he who has it not, can by no temporary exertion attain. The attempt itſelf is a proof, however, that I indulge expectations o fa very different kind.

A 4 I believe

I believe I ſcarcely need remind the man of ſcience, that the great number of labourers in the chemical examination of bodies, has rendered it a difficult taſk to collect the various facts, which lie diſtributed in the acts of academies, and a variety of literary journals. It is not very eaſy to procure theſe books: and the peruſal of them produces a voluminous table of references; in which ſome things may be overlooked, even when noted. A certain degree of imperfection muſt ariſe, in every general treatiſe, from this cauſe. I have endeavoured to diminiſh it as much as was in my power.

In treating of facts long ſince eſtabliſhed, and ſuch whoſe diſcoverers are unknown to me, I have not quoted my authors; for, though I would gladly do juſtice to all claims, yet the inveſtigation of chemical hiſtory is foreign to the object of my preſent purſuit. Whenever I have quoted, it is to be underſtood that the authors are worthy of credit and reſpect; and that the reader will, in almoſt every inſtance, find his advantage in conſulting them for a fuller account of the ſubject. But I have quoted theſe only when it appeared neceſſary either to complete the information intended to be conveyed, or to clear myſelf from ſeeming to lay claim to their diſcoveries.

With regard to nomenclature and theory, I have attempted to keep clear of every ſyſtem. I have called things by ſuch names as are moſt in uſe, except where the uſual name pointed too evidently at theories either long ſince exploded, or not yet proved: and in the relation

relation of facts I have found it much less difficult to exclude theoretical allusions than I at first apprehended, when I formed the determination of confining the theory, for the most part, to the ends of chapters. It would be very advantageous to science if this resolution, which I have adhered to with my best endeavours, were more generally adopted. I do not, however, wish to be thought blind to the advantages of an uniform nomenclature, or a consistent theory; but must urge my conviction that the former ought to be founded on the most incontrovertible facts only, because the nomenclature of any mere theory may be productive of worse consequences than the most confused set of terms can possibly occasion. The systemizing of words, instead of things, is the fruitful source of paralogism; and it is by false reasoning of this kind that a well-methodized hypothesis may be supported, long after the pretended facts are overthrown upon which it was originally built. Upon the two theories of chemistry I have spoken like one who admits neither in any other way than as probable suppositions, which have not yet been experimentally established. The logic of the managers of the controversy for and against phlogiston, appears to me to be exceedingly defective in a great number of instances. The existence of this chemical element is indeed very far from being well ascertained; but, on the other hand, there are many difficulties which attend the consideration of chemical facts without it. As I think the antiphlogistic hypothesis equally probable with the modified

modified ſyſtem of Stahl, and more eſpecially as the excellent works of a number of French chemiſts are written in the language of that hypotheſis, I have judged it proper to explain both. And this I have endeavoured to do in ſuch a way, as to create in the chemical ſtudent an habit of ſteadily and calmly attending to the operations of nature; inſtead of indulging that haſty diſpoſition for theorizing, which indeed might paſs, on account of its evident impropriety, without any earneſt cenſure, if we had not the mortification to ſee it too much practiſed by men entitled to the beſt thanks of the ſcientific world, and on that account poſſeſſing greater power to miſlead.

London,
Jan. 25, 1790.

I HAVE carefully reviſed the Third Edition of this Work: the new diſcoveries are inſerted; and no exertions have been ſpared to render it worthy of the diſtinguiſhed approbation it has met with.

London,
Jan. 25, 1796.

CONTENTS.

BOOK I.

GENERAL CHEMISTRY.

 ture

BOOK II.

PARTICULAR CHEMISTRY.

SECTION I.

OF THE GENERAL PRINCIPLES OF BODIES.

SEC.

SECTION II.

CONCERNING THE MINERAL ACIDS, AND OTHER MINERAL BODIES WHICH ARE CONVERTIBLE INTO ACIDS.

SECTION III.

OF METALLIC BODIES.

SECTION IV.

OF MINERAL COMBUSTIBLE BODIES, AND THE DIAMOND.

SEC.

SECTION V.

CONCERNING THE PRODUCTS OF THE VEGETABLE KINGDOM.

volatile

SECTION VI.

CONCERNING THE PRODUCTS OF THE ANIMAL KINGDOM.

A P P E N D I X.

VARIOUS TABLES USEFUL TO CHEMISTS.

NOTE.

NOTE.

IN the fourth Chapter of the firſt Book of this Work I had obſerved in a note, to the firſt Edition, that very complete ſets of ſmall apparatus for experiments with the blow-pipe, and with ſmall retorts and receivers, were ſold in London, under the inſpection of Mr. Magellan, by Brown, Bookſeller, Eſſex-ſtreet, in the Strand. The death of that worthy and active philoſopher induced me to cancel the note in the preſent Edition; but as Mr. Brown has ſince acquainted me that he has a conſiderable number of ſets remaining, I think I ſhall do a ſervice to the Chemical Student by repeating the information in this place.

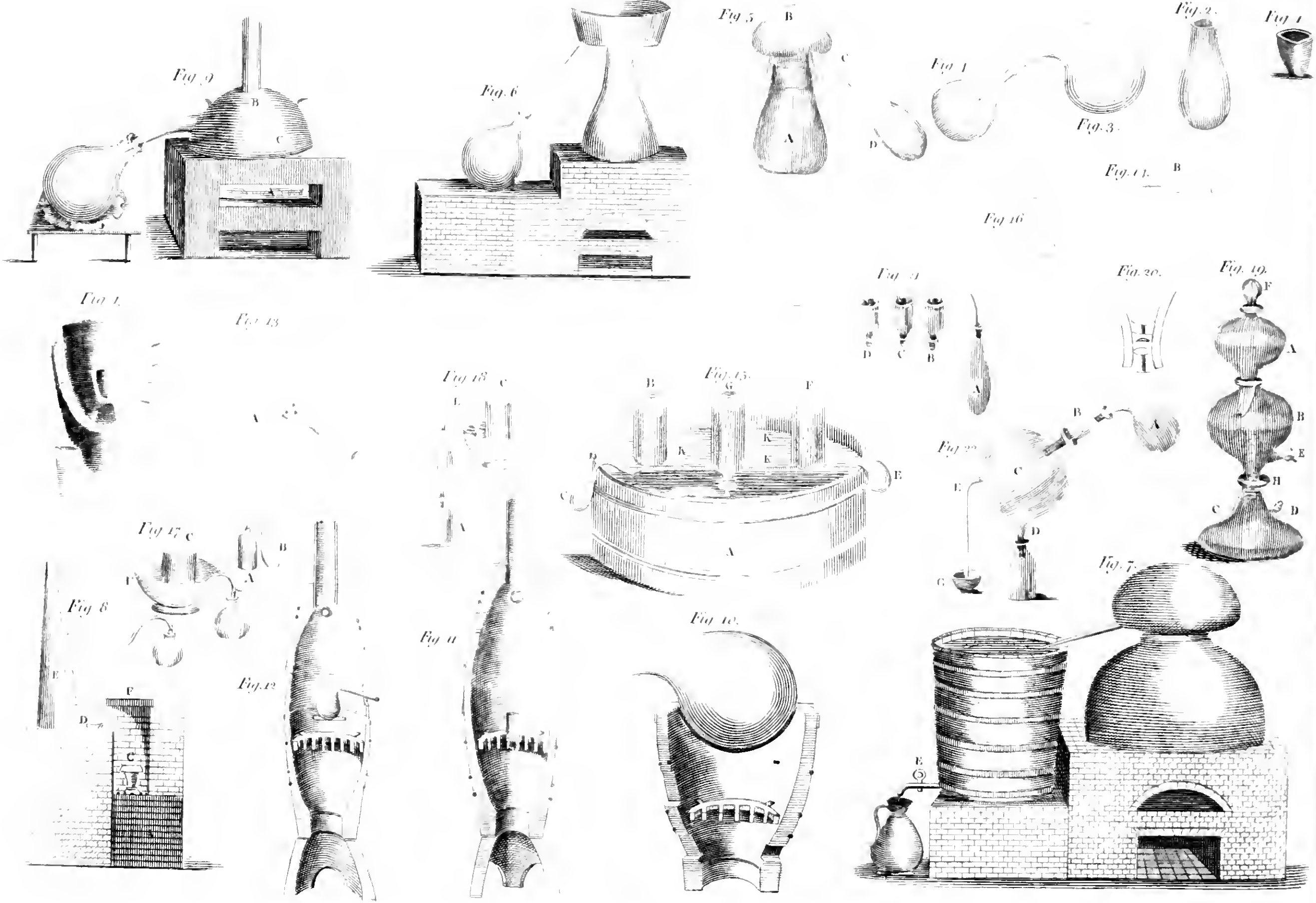
Fig. 9
Fig. 6
Fig. 5
Fig. 2
Fig. 3
Fig. 16
Fig. 13
Fig. 18
Fig. 15
Fig. 20
Fig. 19
Fig. 17
Fig. 8
Fig. 12
Fig. 11
Fig. 10
Fig. 7

BOOK I.

GENERAL CHEMISTRY.

CHAP. I.

GENERAL OBSERVATIONS ON CHEMISTRY, AND THE MEANS BY WHICH ITS OPERATIONS ARE PERFORMED.

GENERAL OBSERVAT.

Chemiſtry defined.

CHEMISTRY may be conſidered either as a ſcience or an art. As a ſcience, its object is to eſtimate and account for the changes produced in bodies by motions of their parts which are too minute to affect the ſenſes individually. As an art, it conſiſts in the application of bodies to each other, in ſuch ſituations as are beſt calculated to produce thoſe changes.

Analyſis.

Syntheſis.

The operations of chemiſtry are either analytical, when compounded bodies are reſolved into their ſimpler parts; or ſynthetical, when ſimple bodies are united ſo as to form a compound. The former operation is called decompoſition; and the latter compoſition, or combination. There are few, and perhaps no chemical proceſſes, in which one of theſe effects takes place without the other.

Heat expands ſolids, then renders them fluid, and afterwards converts them into vapour; and theſe

GENERAL OBSERVAT. Heat.

changes ſucceed each other as the intenſity of the heat is rendered greater. There are many bodies not ſuſceptible of all theſe changes: but it is highly probable that this is owing to our want of power to produce a ſufficient degree of heat or coldneſs, and not to the peculiar nature of the bodies themſelves.

Analyſis by heat.

The heat required to render different bodies fluid or elaſtic, being different, affords a method of ſeparating the parts of compound bodies. If one part of a compound body be rendered fluid, while the others remain ſolid, the former will flow into the lower part of the containing veſſel, and leave the pores of the latter empty: or if one part be converted into vapour, it will riſe and fly off, leaving the other parts, whether ſolid or fluid, in the veſſel. Thus, when a mixture of lead and copper is expoſed to a gradual heat, the lead melts firſt, and leaves the copper. And if a mixture of water and ſalt be heated, the water being converted into vapour, flies off, and leaves the ſalt behind.

Attraction.

All the parts of bodies attract each other. It is not neceſſary in this place to enquire, whether that attraction which cauſes bodies to gravitate or have weight, and by the energy of which the great motions of the planetary ſyſtems are governed, be the ſame as the attraction which cauſes their parts to adhere, and gives them firmneſs or ſolidity. It is enough that obſervation has not yet eſtabliſhed the truth of this propoſition; and, conſequently, it will be proper to conſider the attraction that is perceived to obtain in chemical operations, as a diſtinct property of matter.

The attractions which are obſerved in chemiſtry, are not found to have efficacy at any ſenſible diſtance between

between the parts; but doubtlefs, like the attractions of gravity, magnetifm, and electricity, they are ftronger the lefs the diftance. The rigidity and permanent forms of folid bodies prevent many of the parts of two feveral bodies from coming near each other: for which reafon, very little change is in general produced by their mutual action, even in the moft favourable cafe, when powders are mixed together. But when one or both of the bodies is heated fo as to become fluid, the particles eafily move among each other, and can more readily obey the attractions which exift between them. Hence it has been confidered as a chemical axiom, that bodies do not act on each other, unlefs one of them be fluid.—This affertion is liable however to the exception, that folid bodies will combine at a temperature too low to render either of them fluid, provided it be high enough to fufe the compound they form. Thus ice and falt will combine at a much lower temperature than would liquefy either alone, if the temperature be not fo low as to freeze the brine they form by uniting.

Chemical attractions —act by means of heat.

The whole art of the chemift therefore confifts, either in feparating the parts of bodies by the application of heat, or in placing them fo that the order of arrangement of their parts may be changed by virtue of their feveral attractions, affifted by heat fufficient to fufe one or more of them, or at leaft fufficient to produce fufion in the compound.

Art of the chemift.

Since the order of arrangement of the parts of bodies is changed, when the chemical attractions are permitted to act, by a due fituation of bodies with refpect to each other; it clearly follows, that the attraction between fome kinds of bodies is ftronger than between others.

Elective attractions.

GENERAL OBSERVAT.

others. This difference was formerly supposed to proceed from a similitude between the attracting bodies, and for that reason the attraction has been called the chemical affinity of bodies. But the term elective attraction is at present more generally used to denote this property.

Dry and humid Way.

Though the operations with bodies that require a very strong heat to render them fluid, do not essentially differ from those which are made with such bodies as are fluid at the usual temperature of the atmosphere; yet, as the apparatus for producing and maintaining the heat in the former case is unnecessary in the latter, it is found convenient to distinguish the two methods by different appellations. Operations made with bodies habitually solid, which of course require to be acted on by a strong heat, are said to be made in the dry way; but operations wherein any substance is employed which is habitually fluid, are said to be made in the liquid, humid, or moist way. No distinctive appellation has yet been generally adopted for operations made with elastic fluids; though some call this the pneumatic method.

Terms of art.

In every science or art there are many things which require to be frequently mentioned. If these were described as often as they are mentioned, it is obvious that a great loss of time would follow; and no advantage would be gained in perspicuity, because these descriptions would continually divert the mind from the leading object. For this reason it is absolutely necessary to express such things by single words or terms, which, when once understood, may always afterwards be used in the same sense. These will be explained in the following treatise as they occur.

CHAP. II.

ON HEAT.

HEAT. Of the word heat.

THE fenfations expreffed in common language by the words heat and coldnefs, are of too fimple a nature either to require or to admit of definition. Thefe words, however, are not always ufed to denote the fame things; but are indifcriminately applied both to the fenfation itfelf, and to that which caufes it. Thus we fay that we ourfelves are hot or cold, and that the fire or ice which heats or cools us is likewife hot or cold, though the fenfations we experience are certainly very different things from that which enables bodies to excite them. It may alfo be remarked that, in this ambiguous manner of fpeaking, there is another caufe of uncertainty, that arifes from the ufe of a variable ftandard of comparifon. Every one knows that the eftimate of heat or coldnefs differs in various perfons, becaufe each forms his judgment from his own fenfations: and the fame body may appear hot to one perfon, and cold to another, or to the fame perfon at different times; though the variation is not in the body itfelf, but in the ftate of the perfons in whom thofe fenfations are excited. Hence it appears neceffary, in order to avoid error in the purfuit of enquiries concerning heat, that the fenfe of the words made ufe of fhould be accurately defined; and that fome fixed ftandard of comparifon be referred to inftead of the human body, which, though fixed enough for the common affairs of life, is certainly not enough so for the purposes of science.

Word heat.

The word heat, in a philosophical sense, is used to denote the cause of the power which bodies possess of exciting the sensations of heat or coldness.

Temperature.

The word temperature denotes the state of the body with respect to that power. So that a body which excites a more intense sensation of heat or coldness than another body, is said to possess a higher or lower temperature.

Cause of temperature.

It has not yet been determined in what heat itself, or the cause of temperature, consists. Two opinions have long divided the scientific world. One is, that heat consists of a peculiar motion or vibration of the parts of bodies, so that the temperature is higher the stronger the vibration: the other is, that heat is a substance or fluid, whose greater or less quantity produces a higher or lower temperature. Though the decision of this great question is highly deserving of the attention of philosophers, yet it will not be necessary to consider its merits in this place; and that more especially, as the doubts respecting it will not impede our reasoning concerning such phenomena as are well known. For since effects are proportioned to their adequate causes, we may speak of the quantities of heat in bodies, without deciding whether they be quantities of motion or quantities of matter; the relations of those quantities to each other, and not their peculiar nature, being the chief object of our research.

Common temperature.

Two bodies which, when in contact, neither impart nor receive heat from each other, are of the same temperature.

HEAT.

perature. All bodies, therefore, which by direct or successive contact communicate with each other, must either have the same temperature, or the hotter will communicate heat to the others, till a common temperature is produced amongst them.

Conductors of heat.

The disposition or power of quickly transmitting heat in the production of a common temperature, is not the same in different bodies. If a number of straight wires of equal sizes, but different metals, be covered each with a thin coat of wax, and their ends be all plunged in the same heated fluid - for example, melted lead—the fusion of the coat of wax will shew that heat is more quickly transmitted through some metals than others. Thus also it is found, that the end of a glass rod may be kept red-hot for a very long time, without any inconvenience to the hand which holds the other end; though a similar metallic rod, heated in the same manner, would very soon become too hot to be held. Bodies that quickly alter their temperature by communication, are said to be better conductors of heat than such as alter more slowly.

Solid, fluid, and vaporous states.

The general effects of a change of temperature are these:—A solid is rendered fluid by an increase of temperature, and a still greater increase converts it into elastic fluid or vapour. If the body be composed of parts which become solid, fluid, or vaporous, at different temperatures; and the elective attraction by which those parts are held together be insufficient to prevent their assuming those states by the change of temperature, a separation will then take place: thus a diminished temperature separates many salts from water, by their becoming solid; and an increased temperature se-

HEAT.

Expanfion by heat.

parates water from falts, by caufing the former to fly off in vapour. Laftly, if neither the change of temperature be confiderable enough to alter the ftate of folidity, fluidity, or vapour, which the body under confideration may happen to poffefs; nor the body itfelf be of that nature as to undergo a feparation of its parts by the change; then an increafe of temperature will caufe an increafe in the bulk or dimenfions of the body, which will laft no longer than during the time of the increafe.

Changes by heat do not follow the denfity, &c. of bodies.

It has already been obferved, that the temperature at which different bodies change their form, is various. Neither this property, nor the expanfions of bodies by heat, have been obferved to have any correfpondence with their denfity, hardnefs, fpecific gravity, or other evident properties. There are likewife fome irregularities in the contraction or expanfion, which depend on circumftances not yet well afcertained, near the freezing point of water, and probably other fubftances. Pure water, when cooled, is obferved to contract till within about 8 degrees of the freezing temperature, where it begins to expand; and it may be cooled 11° below that temperature, and ftill continue fluid. An adequate explanation of the circumftances that attend the converfion of bodies from their feveral ftates, of folidity, fluidity, and vapour, feems to promife a more intimate acquaintance with the nature and properties of the particles of bodies than has hitherto been obtained.

Irregularities.

Elaftic fluids.

Permanently elaftic fluids, or airs, appear to differ from vapour in the circumftance that they take and retain the elaftic form at a lower temperature. There are

are facts which render it probable, from analogy, that a great degree of cold would convert them into denſe fluids.

Quantity of heat in equal bodies:

It is a ſelf-evident truth, that if two bodies be perfectly equal and alike in all reſpects, and have the ſame temperature, they will poſſeſs equal quantities of heat. Thus, a pound of gold will poſſeſs an equal quantity of heat with another pound of gold, at the ſame temperature; a pound of water will poſſeſs an equal quantity of heat with another pound of water, at the ſame temperature; and ſo forth. From this it will alſo be clear, that two pounds of gold will poſſeſs twice as much heat as one pound of gold, at the ſame temperature; and, generally, that the quantities of heat in bodies of the ſame kind, and at the ſame temperature, will be in proportion to their quantities of matter or their weights.

—differing in temperature

If two ſuch equal and ſimilar bodies, that differ in temperature, be brought together, they will by communication acquire a common temperature, and their quantities of heat will by that means be rendered equal. For this purpoſe it is clear that the hotter of the two bodies muſt have communicated half its exceſs to the colder: the quantity of heat in one of theſe two equal bodies will therefore be an arithmetical mean between the two quantities originally poſſeſſed by each of them; that is to ſay, its temperature, or the common temperature, will exceed that of the colder exactly as much as it falls ſhort of that of the hotter body.

—in unequal bodies.

If the two bodies had been unequal, they would nevertheleſs have acquired a common temperature by communication, but the exceſs of heat would not have been

HEAT.

been equally divided between them; for we have ſhewn that the quantities of heat in ſuch bodies, at the ſame temperature, are in proportion to the quantities of matter. If the ſurplus of heat had been entirely taken away, it is obvious that their temperatures would have been made equal, and their heats would have been in that proportion; and there is no other way of adding the ſurplus to them, ſo as to preserve the ſame proportion, but by giving more to the larger than to the ſmaller body, according to its quantity. The common temperature they acquire ſhews that this is done; and conſequently that, when two unequal bodies of the ſame kind acquire a common temperature by communication, the exceſs of heat in the hotter body is divided between them in proportion to their weights or quantities of matter.

Quantities of heat required to change temperature.

From this it is likewiſe evident, that the quantities of heat required to be added to or taken from bodies of the ſame kind, to produce equal changes in their temperature, will be in proportion to their quantities of matter.

Thermometer;

The foregoing deductions naturally lead us to the conſideration of an inſtrument proper to ſhew the temperatures of bodies. Such an inſtrument will require to be placed in contact with the body under examination, in order that it may acquire the ſame temperature. It is therefore an indiſpenſable condition, that the inſtrument ſhould be of that ſmall bulk as not ſenſibly to heat or cool the body it touches; but that the common temperature of the inſtrument, and the body itſelf upon contact, may, without perceptible error, be taken for the original temperature of the

—its requiſites.

 body.

body. Another condition equally requiſite is, that every change of temperature ſhall be attended with ſome evident change in the inſtrument by which it may be aſcertained. The expanſions and contractions of bodies are the moſt convenient for this purpoſe. Theſe, however, are ſmall; and would require to be magnified by ſome mechanical or optical contrivance, if a ſolid body were made uſe of. But the ſmalleſt change in the bulks of fluids may be eaſily ſhewn by the happy expedient of including them in a bottle whoſe neck is long, and very narrow, in proportion to the diameter of its body. On theſe conſiderations the thermometer is made. It conſiſts of a glaſs ball or bottle, with a long narrow tube or neck, and is partly filled with mercury; a fluid preferable to all others, from its unchangeableneſs, the regularity of its expanſions, and its not ſoiling the tube. The expanſions or contractions of the mercury are ſhewn by the riſe or fall of its ſurface, which is meaſured by a graduated ſcale uſually fixed to the tube.

Mercurial thermometer.

The determination of the correſpondence between the degrees of the thermometer, and the actual variations of the heat of fluids, was firſt accurately determined by Mr. De Luc. By mixing equal quantities of water at different temperatures, he found that the thermometer very nearly indicated the arithmetical mean between the two temperatures, and conſequently that its indications are ſuch as truly correſpond with the quantities of heat.

Correſpondence of the expanſions of mercury with the increments of heat aſcertained by De Luc;

As theſe fundamental experiments cannot be too ſtrictly examined, the following doubt remained to be conſidered, namely, whether the diſpoſition to give out

—by Crawford.

or

HEAT.

or to receive heat, were the ſame in water at all temperatures; becauſe it is clear that, if this diſpoſition be changed by heating or cooling, the temperature, or power to heat or cool other bodies, will not follow the ſame proportion as the quantities of heat; though it may be imagined, not without probability in this caſe, that correſpondent irregularities in the expanſions of the mercury, may cauſe the thermometer to indicate the arithmetical mean between the two expanſions produced by any extreme temperatures. But whatever irregularities may be ſuppoſed to counteract each other in theſe experiments with mercury and water, it is to the laſt degree improbable that the ſame compenſation would be found, when the mean temperature is obtained by other methods. With this view the celebrated Dr. Crawford * very carefully repeated and confirmed Mr. De Luc's experiments; made others with a like reſult, by uſing linſeed oil inſtead of water, and alſo by producing the mean temperature, permanently, in air included in a cylinder formed of two equal parts, the upper of which was kept to the freezing point, by ſurrounding it with pounded ice; and the lower to the boiling-water point, by ſurrounding it with a greater ſupply of ſteam than could be condenſed by its contact. The near correſpondence of theſe ſeveral methods ſhews that the expanſions of the mercury in the thermometer are correſpondent with the heat it receives.

* On Heat. London, 1788. This moſt valuable performance contains the theory, and moſt of the facts, relating to heat; and deſerves to be made a part of the library of every natural philoſopher.

Thus

HEAT.

Thus far we have attended only to the communication of heat between bodies of the fame kind; but when two equal bodies of different kinds produce a common temperature by communication, it feldom happens that it proves to be an arithmetical mean between the two original temperatures. In fuch cafes it is evident that the heat which was communicated from one to the other, has not altered their temperatures equally, but has raifed or lowered that of the one more than it has lowered or raifed that of the other. And as the proportion between the number of degrees through which one of two bodies is thus raifed, and the other lowered, is found by experiment to be the fame, however different the two original temperatures may have been, provided no change of form or chemical combination has been produced in either of them; it is a general confequence, that the quantity of heat required to alter the temperature of one of the bodies a fingle degree, or any other equal part, will be greater or lefs than would be required to produce the fame change in the other body, in proportion as the changes produced by the communicated heat were lefs or greater. Quantities of heat in bodies of different kinds: —relative.

The whole heat in each body, when they have the fame temperature, muft confift of the fame number of degrees: the proportion between the whole heats of the bodies will therefore be the fame as between the heats required to raife each of them a fingle degree: that is to fay, the comparative heats of bodies, at the fame temperature, will be in the inverfe proportion of the number of degrees their temperature is altered by the fame quantity of heat. —abfolute.

To illuftrate this by an example in round numbers. Example.

Suppofe

HEAT.

Suppose a pint of mercury, at the temperature of 136°, be mixed with a pint of water at 50°, the mean temperature will be 76°. The water therefore has been heated 26°, and the mercury has been cooled 60°, by the loss of the heat it imparted to the water. The absolute heat in one degree of the mercury will consequently be proportionally less than that of one degree of the water; because the very same heat which has raised the water 26 degrees in temperature, would raise the mercury 60, if it could be returned again: and the whole heat contained in the mercury will be to that of the water in the same proportion of 26 to 60. But in the present experiment equal bulks were used; and mercury is about 13 times as heavy as water. An equal weight of mercury would contain only one-thirteenth part of the heat. Twenty-six, divided by 13, quotes 2: whence the comparative heats of mercury and water are in the proportion of about 2 to 60, or 1 to 30; that is to say, a pound of mercury, at the same temperature, contains no more than one-thirtieth part of the heat contained in a pound of water.

Comparative heat.

It may be observed that the term comparative heat is used to denote the proportion of the absolute quantity of heat in one body to that of another equal mass of matter at the same temperature, considered as a standard. The standard made use of is pure water, in a fluid state. Some writers call this specific heat. The disposition, or property, by which bodies severally require more or less heat to produce equal changes in their temperature, is called their capacity for heat. These capacities are considered as the unknown cause of the differences in their comparative heats, to which they are consequently proportional.

Capacity.

It

It is found, by experiment, that the capacity of the same body for heat is leaft when folid, greater when fufed or fluid, and greateft of all when it becomes converted into vapour, or elaftic fluid. Capacities in various ftates.

Alfo, when bodies unite by virtue of chemical attraction, their capacities are feldom the fame as the fum of the capacities of the bodies, but almoft always either greater or lefs. —changes by chemical actions.

As the experiments relating to the capacities of bodies cannot be here given at large, it will be proper to mention, by way of inference, fome of the chief confequences of this moft luminous doctrine; firft premifing, however, that thefe inductions have all been verified by experiment *. Inferences.

The capacities of ice and fluid water are found to be as 9 to 10. Ice cannot therefore be converted into water, unlefs it be fupplied with as much heat as is fufficient to anfwer the difference of capacity. Thus, if equal quantities of ice and water, both at the temperature of 32°, or the freezing point, be expofed in fimilar veffels, at the fame diftance from a fire, both will receive heat alike; and the ice will be melted into water at 32°, while the water in the other veffel will have its temperature raifed to 178°. Here it is obvious that the fame heat which raifed the water 146 degrees, was merely fufficient to fupply the increafed capacity of the ice; for which reafon this laft had not its temperature raifed at all. If the experiment be more accurately made, by mixing equal weights of water at 178°, and ice at 32°, the fame confequence will follow; Ice and water.

* For which confult Dr. Crawford's Treatife, already fpoken of.

for

HEAT.

for the ice will be melted, and the common temperature will be 32°; becaufe the ice in melting receives no augmentation of temperature, but abforbs the whole 146° of heat from the water, by virtue of its increafed capacity when it becomes fluid.

Stationary temperature, or freezing point.

And fo likewife, when water is frozen by the lofs of its heat, communicated to a cold atmofphere, or other contiguous bodies, the procefs of cooling goes on till ice begins to be formed: but, during the whole time of the converfion of the water into ice, the temperature remains ftationary, becaufe the diminifhed capacity of the ice caufes it to give out heat, the continual evolution of which fupplies the refrigerating bodies with as much as their energy of cooling might otherwife have taken to caufe a diminution of the temperature. When the whole is frozen, this fupply of extricated heat ceafes; and therefore the caufe that cooled the water at firft, goes on in cooling the ice, until the common temperature is produced.

Natural zero of temperature.

In all experiments wherein the capacities of the fame bodies are changed, and the difference between the quantities of heat in the fame body in both ftates, at one common temperature, is known in degrees of the thermometer, we may derive the advantage of finding the abfolute quantities of heat in degrees of the thermometer, or the number of degrees which any particular point or temperature is remote from the true zero, or point of abfolute privation of all heat. To illuftrate this curious pofition, the experiments on ice and water, juft related, may be made ufe of. The whole quantities of heat, in thefe two ftates, are as 9 to 10. It is plain, therefore, that when water freezes, it

HEAT.

it muft give out one-tenth of its whole heat; and this tenth part, by the experiment, is found to anfwer to 146° of Fahrenheit's thermometer. Confequently its whole heat is ten times 146°, or 1460° of Fahrenheit's thermometer, when its temperature is 32° above Fahrenheit's zero. Whence the natural zero* is at —1428°.

Capacity of fteam.

No direct experiment has yet been made to fhew the capacity of fteam with relation to water. An indirect experiment of Dr. Crawford makes it as 15½ to 10 †. It is accordingly found that fteam, in its condenfation into water, gives out as much heat as would raife an equal quantity of non-evaporable matter, of the fame capacity as water, 914 degrees. This heat it muft have taken up at its formation. Whenever water is heated, we may confequently confider the heat as difpofed of in two ways. One part raifes the temperature of the fluid water, and the other part is employed in fupplying the elaftic vapour that flies off with the heat which its increafed capacity requires at that temperature The greater the quantity of fteam is produced, the larger will be the proportion of the heat employed in this laft way. Now, there is a difficulty attends the formation of elaftic vapour, in proportion as its efcape is rendered more difficult. If the water be heated in a clofe veffel, no fteam will be formed; if the fteam efcape by a fmall hole, there will be lefs formed than if the whole furface of the water were uncovered; and if the fuperincumbent atmofphere be removed, as in the vacuum of an air-pump, the production will be greateft of all. As the heat of the

* Crawford, p. 458. † Ibid. p. 270.

HEAT.

water goes on increaſing, the production of ſteam will likewiſe increaſe, until the quantity is ſo great as by its augmented capacity to carry off the whole heat that is communicated. At this period the increaſe of temperature will therefore ceaſe, and the temperature will become ſtationary. This point is called the boiling-water point. It varies, however, a little, as the preſſure of the atmoſphere varies, being loweſt when that is leaſt; becauſe the maximum of ſteam is produced at a lower temperature when the obſtacle to its eſcape is leſs. It has been ſtated, and with ſome probability, that there might be no interval of fluidity between the ſolid and vaporous forms, if it were not for the preſſure of the atmoſphere.

Boiling-water point of temperature.

Evaporation produces cold.

In this manner it is eaſy to account for the cold produced by evaporation: for the volatile ſubſtance, when it takes the vaporous form, abſorbs as much heat from the body from which it evaporated, as its increaſed capacity requires. Every one muſt be acquainted with the cold produced by wetting the hand with water or with ſpirits of wine or brandy. The freezing of water by means of the evaporation of ether, is a very remarkable inſtance of this. Water is included in a thin glaſs tube, and the outſide of the tube is kept continually wetted with ether, by means of a bottle with a capillary tube in its neck, through which the ether is poured. The conſequence of the ſpeedy evaporation of this very volatile fluid is, that in a very ſhort time the included water is ſuddenly converted into ice, even before a fire, or in the midſt of ſummer.

Freezing by evaporation.

Freezing mixtures.

The effect of freezing mixtures is another evident conſequence of this doctrine. When as much common

mon falt is added to water as it can diffolve, the brine continues unfrozen till it is cooled as low as 6° below 0°, on Fahrenheit's fcale. Suppofe pounded ice, or fnow, to be mixed with falt at any temperature above —6°, their union will produce the brine here mentioned; which, becaufe the heat is above its freezing point, will become fluid, though the ice and falt were folid before. This fluidity will be attended with an increafe of capacity, and therefore the brine will be much colder than the fnow and falt were. If the quantity of fnow and falt be confiderable, and there be no bodies at hand which can readily fupply heat, the brine firft produced will cool the fnow and falt in its vicinity; and this, when liquefied, will cool the reft of the fnow and falt ftill more effectually. When the temperature of the whole is as low as—6°, or the freezing point of the brine, the liquefaction and cooling will ftop, or it will proceed more flowly or fafter, in proportion as the requifite heat is fupplied. It may eafily be imagined that, if a mixture of this kind be placed in a veffel, and a fmaller veffel, containing water, be plunged in it, the cooling procefs will freeze the water. It is likewife evident that fuch mixtures will defcend to a fixed temperature, which is that of their own freezing point*.

Fixed temperature of freezing mixtures.

So likewife the freezing proceffes by the folutions † of falts in water or acids, though they have not yet been fo minutely examined, may be explained from the difference of capacity produced in the liquefaction of folid falts, or the water contained in them. One of

Freezing proceffes by diffolving falts in water.

* Crawford, p. 474.

† Walker, in Philof. Tranf. vol. lxxvii and lxxviii.

HEAT.

Mixture of falts for freezing water.

thefe may be here mentioned, not as the moft powerful, but becaufe the materials are cheap, and well known. It confifts of equal parts of fal ammoniac and faltpetre, finely powdered. If four ounces of water be poured on three ounces of this mixture, the folution will fink the thermometer 36 degrees; and as it is eafy to have pump-water as cool as 50° in the midft of fummer, this addition will cool it to 14°, which is therefore fufficient to freeze water in a phial plunged in it.

General view of the agency of heat.

Without entering more largely into examples of the confequences of the change of capacity in bodies which are changed in their form, or ftate of chemical combination, it may be obferved, in general, that as the powers of gravity and projection, in continual oppofition to each other, produce all the beautiful effects in the great fyftem of the univerfe to which they are effential; fo, among the actions of the minute parts of bodies, the cohefive attraction, and the energy of heat, are in continual oppofition to each other, and are concerned in every procefs by which changes are produced in the peculiar properties of bodies: and for whatever more immediate purpofes it may be that the Supreme Intelligence has thus generally appointed their agency, we fee that the changes of capacities are greatly conducive to the prefervation of a more equal temperature than would otherwife be found in the diftricts around us. The cold produced by evaporation greatly mitigates, and conducts to other parts, the ftrong heats of the torrid zone; and the heat developed on the freezing of water prevents the cold from falling fo far below the freezing point as otherwife it might

Advantages arifing from the changes of capacities.

 do

do. If the capacities of water and ice were equal, the freezing of immenſe bodies of water would ſcarcely be progreſſive, but would take place the inſtant the whole was cooled to 32°; and ſo likewiſe the thawing of vaſt tracts of ſnow and mountains of ice would be performed in the ſhort time of the tranſmiſſion of the heat required to raiſe its temperature the minuteſt portion of a degree above the temperature of ſolidity. Whether the extreme inconveniences the hotter climates would undergo from increaſed heat, or the colder from the intenſe freezing and ſudden thaws, be among the principal events in the view of the Sovereign Diſpoſer of the univerſe, cannot, from our ignorance of final cauſes on ſo large a ſcale, be determined.

Whether heat be matter or motion, is a queſtion which, as was before obſerved, is not well ſettled. It is certain that the motion of friction, or percuſſion, either produces or collects heat; and if the ſuppoſition of the mere vibration of parts could adequately account for the effects, it would doubtleſs be more ſimple than to call in the aſſiſtance of a material ſubſtance endued with peculiar properties. But, on the other hand, the appearances are ſolved with great eaſe and ſimplicity by the ſuppoſition of ſuch a ſubſtance. On this ſubject it may perhaps be ſufficient to obſerve, that the phenomena of heat ſeem to ſtand ſingle, ſo as not eaſily to admit of compariſon with any of the other appearances in nature; and conſequently that all reaſoning by analogy promiſes very little elucidation of a ſubject which can only be proſecuted by experimental reſearch.

Queſtion, p. 6.

The philoſophy of heat admits no analogy.

HEAT.

Diminution of capacity increases weight.

Attempts have been made to determine whether the weight of bodies is affected by the greater or less quantity of heat they may contain. The most accurate experiments shew that the same water is heavier, by a very minute quantity, when it is converted into ice.

Dr. George Fordyce made the experiment by weighing the same quantity of water (about 1700 grains), when frozen and when unfrozen, at the temperature of 32°, in a room where the air was of the same temperature. The ice was near one-sixteenth of a grain heavier. Phil. Transf. vol. lxxv. p. 362.—Sir Benjamin Thompson obtained the same conclusion, by counterpoising water against spirit of wine, and exposing the apparatus to a cold atmosphere which froze the former.

CHAP.

CHAP. III.

THE CONSTRUCTION OF THE THERMOMETER.

THERMOMETER.

Construction of the thermometer.

IN the prefent cultivated ftate of philofophical knowledge, it can hardly be fuppofed that the reader has not feen a thermometer. Minute defcription is therefore unneceffary. But as the accurate conftruction and fubfequent improvement of this inftrument muft greatly depend on the knowledge, which thofe who ufe it may poffefs, of the method of making it; and as we have no perfect account of this, there can be no doubt but a fhort relation of the whole procefs, from experimental knowledge, will be acceptable.

To determine the cylindrical form of the bore.

The tubes may be had at the glafs-houfe; and the firft care of the artift muft confift in examining if their cavities be equal or cylindrical throughout. This is done by immerfing one end into mercury, and withdrawing it, after clofing the other end with the finger. By this means a fmall quantity of mercury will enter the tube, which will occupy a longer fpace the deeper the tube is immerfed. Lay the tube horizontally upon a graduated rule, and obferve the length of the mercurial column, in different parts of the tube to which it may be made to run, by inclining it more or lefs. If the length continues invariably the fame, it is a proof that the tube is uniformly cylindrical; but, if otherwife, the diameter varies, and the tube cannot be ufed to make a good thermometer, unlefs the graduations in the dif-

THERMOMETER.

ferent parts of the tube be lengthened or ſhortened, in proportion to the meaſures of the mercurial column.

Method of blowing thermometers.

Direct the flame of a large candle, a watchmaker's lamp, or, which is cleanlieſt and beſt of all, a lamp with ſpirits of wine, upon one end of the glaſs tube, by means of the blow-pipe. The extremity will ſoon become red hot, and in a ſtate of imperfect fuſion. Remove the tube from the flame, and blow into its other end, and the heated part will be inflated ſo as to form a bulb. This laſt inflation is the moſt difficult and laborious part of the buſineſs; but it may be performed with great eaſe and advantage, by previouſly faſtening the neck of one of the ſmall bottles of elaſtic gum, or India rubber, about the end of the tube; which, when the other end is ignited, may be preſſed by the hand, ſo as to blow the bulb very commodiouſly, and without the introduction of any moiſt air.

Filling with mercury.

Immerſe the open end of the thermometer tube into ſome very clean dry mercury that has been boiled, and warm the bulb with a candle; part of the air will be immediately heard ruſhing through the mercury; withdraw the candle, and, as the bulb cools, the mercury will riſe in the tube. This will be facilitated by holding the tube as near an horizontal poſition as can be done, without raiſing its lower end above the ſurface of the mercury. In this way the bulb will be nearly half filled. Without altering the poſition of the apparatus, move the whole ſo that the bulb may be held over a candle. A ſmall candle newly ſnuffed is beſt, becauſe of the ſteadineſs of its flame; and it will be neceſſary to wrap a piece of paper round the tube, to defend

defend the finger and thumb from its heat. The mercury will ſoon boil, and moſt of the remaining air will be heard eſcaping from the bulb. As ſoon as this eſcape has ceaſed, remove the bulb from the candle, and it will be ſuddenly filled with mercury from the veſſel.

Boiling the mercury in the tube.

Take the thermometer thus filled out of the mercury, and wrap round its open end a piece of thin paper, in ſuch a manner as to leave a cavity beyond the tube, at leaſt ſufficient to hold as much mercury as the bulb contains; ſecure this by wrapping it tight with packthread about the tube; then put a drop of mercury into the paper cavity, and apply the bulb again over the ſnuffed candle, holding the tube upright between the finger and thumb, or a pair of ſmall pincers, at the part wrapped with paper and packthread: the mercury will ſoon boil, and about half the contents of the bulb will ruſh violently up the tube into the paper. Remove the bulb from the candle, and the mercury will ſuddenly return; then boil it again; and repeat the operation till the ſpeedy boiling of the mercury, when placed over the candle, and the diminiſhed noiſe and agitation, ſhew that the whole has been well heated, and deprived of the air or moiſture which might have adhered to it.

Caution.

The operation of boiling will fail, if the mercury, or the inſide of the bulb, be moiſt; for in this caſe the bulb is uſually burſt by the mercurial vapour; the exploſion however is not dangerous: it is very likely to happen with bulbs blown by the mouth, unleſs they be kept ſome weeks in a dry place, before they are filled. The ſame danger makes it prudent not

to

to boil the mercury ſtrongly the firſt or ſecond time; and it is likewiſe of importance to keep the bulb clear of the flame, as the contact of this laſt againſt the empty part of the bulb would melt it, and a hole would be immediately made by the excluded vapour.

Trial of the proportion between the bulb and the tube.

After the boiling is completed, plunge the bulb into cold water, whoſe temperature is known. Melting ice or ſnow (or ſnow and water) always has the temperature of 32° of Fahrenheit's ſcale. Then take off the paper, and put the bulb into the hand, and afterwards into the mouth; this heating will cauſe ſome of the mercury to drop out of the tube. Cool it again to 32°, by immerſing it in the cold water, and mark where the mercury ſtands. The diſtance between this ſtation and the top of the tube meaſures the interval between freezing and blood heat, or 32 and 95, which makes 63 degrees; and will conſequently ſhew whether the degrees will be large or ſmall, and what extent the ſcale is capable of; that is to ſay, it will ſhew whether the bulb is of the proper ſize. This laſt, ſuppoſing the judgment of the operator not ſufficient to proportion the bulb nearly to the tube, and the intended ſcale, might however have been more conveniently aſcertained after the firſt filling, before the boiling had been undertaken.

Hermetical ſealing of the tube.

When the number of degrees to which the length of the tube will extend is thus known, the operator muſt ſettle whereabouts he will have the freezing point, which may be nearer or farther from the bulb, accordingly as he intends the instrument to be uſed, more particularly to aſcertain great degrees of heat,

or

or of cold. At this ſtage of the buſineſs, likewiſe, he may heat the upper part of the tube with the blow-pipe, and draw it out to a fine capillary tube ready for ſealing. The bulb muſt then be heated in the candle, till a few particles of mercury have fallen off the top of the tube; and notice muſt then be taken how much nearer the freezing point is to the bulb than before, which may be done by immerſing it in the melting ſnow, as before. If it be not as low as deſired, the heating muſt be repeated, carefully obſerving not to throw out too much mercury at a time. When the due quantity of mercury is thus adjuſted, two candles muſt be prepared, the one to heat the bulb, and the other to cloſe the tube. The blow-pipe being in readineſs, the upper part of the tube near the flame of one candle, and the bulb near the flame of the other, the mercury will riſe, and at laſt begin to form a globule at the point of the capillary tube. At this inſtant the bulb muſt be withdrawn from the lower candle, at the ſame time that the flame of the upper is directed by the blow-pipe upon the point of the tube. This laſt will be immediately ignited, and will cloſe by the melting of its parts, before the mercury has perceptibly ſubſided. When the mercury has fallen, this cloſure may be rendered more ſecure from accidental breaking, by fuſing the whole point of the tube, till it becomes round.

Proof of internal vacuum.

If this buſineſs be properly done, the mercury in the inſtrument thus filled will run backwards and forwards in the tube, immediately upon inverting its ſituation.

In

THERMOMETER.

Adjuftment of the fixed points.

In the original graduation of thermometers, two fixed points of temperature are neceffary. Thefe are the freezing point of water, or temperature of ice or fnow, at the inftant of formation, or rather when it is juft beginning to liquefy; and the boiling point of water, or temperature at which, under a known preffure, it is plentifully converted into fteam. For the fettling the freezing point, nothing more is neceffary than to immerfe the thermometer fo deep in melting fnow or ice, as that the mercury may be barely vifible above its furface, and carefully mark the place at which it ftands. The boiling point is not quite fo eafily afcertained; crude, hard, or faline waters acquire a greater heat in boiling than fuch as are purer; and the fame water will acquire a greater heat under a greater preffure. For this laft reafon, the boiling point fhould be fixed according to the decifion of the committee of the Royal Society; namely, when the barometer ftands at 29.8 inches. The beft method is to provide a veffel fomewhat longer than the thermometer, with a cover, and two holes in it; one about an inch in diameter, for the fteam to efcape; and the other fmaller, for the thermometer tube to be faftened in it. When this is ufed, the thermometer muft be faftened in the cover, fo that the eftimated place of the boiling point may be juft above the hole. Water muft be put in the veffel, not fufficient to touch the bulb of the thermometer, when the cover fhall be put on. The veffel muft then be covered, a thin plate of metal laid on the fteam-hole, and the water made to boil by heat applied to the bottom only. The thermometer will be then furrounded with fteam, which will raife its temperature

Freezing.

Boiling.

perature to the boiling point; and this point muſt be carefully marked on the tube. The following method may be more convenient to thoſe who are not provided with ſuch a veſſel:—Wrap ſeveral folds of linen rags or flannel round the tube, nearly as high as the ſuppoſed boiling point; hold the ball of the thermometer in the aſcending current of boiling rain water, about two or three inches below the ſurface; pour boiling water on the rags three or four times, waiting a few ſeconds between each time; and wait ſome ſeconds after the laſt time of pouring on water, in order that the water may recover its full ſtrength of boiling, which is conſiderably checked by the pouring on the rags. The place where the mercury ſtands is the boiling-water point.

Adjuſtment for errors of the tube.

Notwithſtanding the accurate adjuſtment of the fixed points of a thermometer, yet if the tube be not truly cylindrical, or if the diviſions be not adjuſted to the inequalities of its diameter, the errors at the middle, between the two fixed points, may amount to more than a whole degree. A ſmall error in the ſtanding of thermometers may be occaſioned by the varying preſſure of the atmoſphere, which alters the capacity of the glaſs; but it never amounts to ſo much as the tenth part of a degree. Spherical bulbs are leaſt ſubject to this.

Standard thermometer.

Thermometers which, from the great length of their degrees, or for any other reaſon, are made to take in but a ſmall part of the interval between the two fixed points, are uſually graduated by compariſon with a ſtandard thermometer.

The

THERMOMETE

Cafes in which the mercury need not be boiled.

The very careful boiling of the mercury, as above defcribed, is abfolutely neceffary for fuch thermometers as are to be fealed when full: for if there were any air or moifture left in the bulb, it would prevent the mercury in the tube from defcending into the bulb, fo that the tube would continue always full. Thefe thermometers are undoubtedly the beft; but the vacuum above the mercury does not feem to be an indifpenfable requifite. If a clean dry tube be filled with pure boiled mercury, and a fmall bulb be left at the top of the tube, to contain common air, in order that its expanfion or condenfation, produced by the change in the mercurial furface, may be inconfiderable; there will be few practical objections againft fuch a thermometer; more efpecially if it be a fecondary inftrument, graduated by means of a ftandard. There are fome thermometers made with tubes fo very fmall, and bulbs fo large in proportion to them, that they will not admit of boiling the mercury in them, but are filled with boiled mercury by means of a condenfer. Thefe are neceffarily of the kind here mentioned.

Scales of thermometers. Fahrenheit's.

The thermometers moft in ufe at prefent are Fahrenheit's, Reaumur's, and Celfius's. In Fahrenheit's fcale, the number of degrees between the freezing and boiling water point is 180; the freezing point being at 32°, and the boiling point at 212°, both above 0°, or the part from which the degrees are reckoned both ways. In Reaumur's fcale, the number of degrees between thefe two points is 80, and the freezing point is called 0°, from which the degrees are reckoned both ways. In Celfius's thermometer, the interval

Reaumur's.

Celfius's.

terval is divided into 100°, and the freezing point is called 0°, as in Reaumur's. To reduce these scales to each other, it must be observed, that one degree of Fahrenheit's is equal to $\frac{4}{9}$ of a degree of Reaumur, and to $\frac{5}{9}$ of a degree of Celsius. Therefore, if the number of degrees of Fahrenheit, reckoned above or below the freezing point, be multiplied by 4, and divided by 9, the quotient will be the corresponding number on Reaumur's scale. Or if the multiplier 5, and the divisor 9, be used, the quotient will give the degrees of Celsius's scale. And, contrariwise, if any number of degrees, either of Reaumur or Celsius, be multiplied by 9, and divided by 4 if of Reaumur, or by 5 if of Celsius, the quotient will give the degrees of Fahrenheit, reckoned either above or below the freezing point, as the case may be.

THERMOMETERS. Reduction of degrees of thermometers of various scales.

CHAP.

CHAP. IV.

ON COMBUSTION, AND THE APPLICATION OF HEAT TO CHEMICAL PURPOSES.

APPLICAT. OF HEAT.

Friction; hammering; flint and fteel.

THE methods of producing an increafe of temperature are various. The friction of two pieces of wood, in a turner's lathe, produces heat and flame: a nail may be made red hot by hammering it: and when flint and fteel are ftruck together, fmall particles of the fteel are feparated, which are in a ftrong ftate of deflagration, and, upon examination with the microfcope, are found to have been fufed into hollow greyifh balls. The fun's light, concentrated by a convex lens, or concave mirror, is likewife found to produce the moft aftonifhing effects, by raifing the temperature of bodies. And, among chemical mixtures, there are many by which ignition and flame are produced. In thefe, and in all inftances where the temperature is raifed, a diminution of the capacities of the bodies appears to be the effective caufe.

Solar focus.

Chemical mixtures.

Combuftion.

Moft operations that require an increafe of temperature, are performed by the communication of heat from bodies in combuftion. The general facts refpecting this wonderful procefs, are the following:—There are certain bodies which, when ignited or heated fo as to become luminous, will foon ceafe to be fo, by the lofs of that heat which they communicate to the bodies around them: but there are others which,

which, if ignited in contact with the air of the atmosphere, will not lose their ignition, but continue to give out heat, till their volatile parts are dissipated, and the properties of the remainder entirely changed. These last are called combustible bodies. It is found by experiment that the capacities or quantities of heat, in combustible bodies, are not considerable; that the quantity of heat in atmospheric air, in the elastic state, is exceedingly great; and that part of this air is absorbed by bodies in combustion. If, therefore, the temperature of a combustible body be by any means so raised, as that the chemical process by which air becomes condensed and combined with it may go on, the temperature of the air will be raised, as its capacity is diminished, in passing from the elastic to the solid state; and it will therefore give out its heat to the combustible body, which, instead of becoming colder, must increase in temperature, in proportion to the quantity of air condensed in the same time, excepting so far as this effect is diminished by the conducting power of the surrounding bodies. Combustion.

The processes which are performed by the simple application of heat, are as follow: Processes,

Roasting.—This consists in exposing mineral bodies to the heat of an open fire, for the purpose of dissipating their volatile contents. Roasting.

Calcination is performed by exposing bodies, in an open vessel, to a strong heat, till no farther change can be produced in them. The body which remains, and withstands the fire, is called a calx. Both these terms are more particularly applied to metals. Such bodies as are very little changed by heat, are called refractory. Calcination.

APPLICAT. OF HEAT.

Fusion. Fusion consists in heating bodies, in proper vessels, till they become fluid. It is chiefly used for the purpose of uniting smaller bodies into one large mass, and casting them into moulds of any desired figure. The facility with which metals may be united in this way, after they have been divided, is probably the circumstance that induced mankind to use them as the mediums of exchange, or signs of value of all other commodities.

Digestion. Digestion consists in keeping bodies for a considerable time immersed in a fluid at a higher temperature than that of the atmosphere, in order that combinations may take place that could not else have been effected.

Cementation. Cementation is a process wherein solid bodies, one or more of them being pulverized, are exposed to heat in proper vessels, with the intention that the more volatile parts of the one body may unite with the other, or with its fixed parts.

Evaporation. Evaporation consists in the dissipating of fluids by heat.

Concentration. Concentration consists in increasing the proportion of saline matter in any watery fluid, either by evaporating part of the water, or by causing it to freeze, and taking away the ice.

Distillation. When evaporation is performed in vessels either perfectly or nearly closed, so that the volatile parts, which are raised in one part of the apparatus, may be received and condensed in the other part, the process is called distillation.

Rectification. Rectification is a subsequent distillation of the product which comes over.

Sublimation. In the distillation of such bodies as are solid in the

the usual temperature of the atmosphere, the vapours are scarcely condensed before they become solid. In this case the process is called sublimation; and the condensed vapours, which usually have a powdery form, are called flowers. Such are the flowers of brimstone, of benjamin, of zinc, &c. Solid products, obtained in this way, are called sublimates. APPLICAT. OF HEAT. Flowers. Sublimates.

Some of these operations may be performed by a common culinary fire, and indeed most of them may when the quantities of matter are small, which is usually the case in philosophical experiments. In the arts, where every process requires to be repeatedly carried on in the large way, a variety of furnaces have been contrived, to suit the various intentions of the operators. But experimental inquiries demand the occasional exertion of every branch of chemical operation; for which reason the furnaces and apparatus ought to be constructed on as general principles as possible. Common fire.

The vessels used in chemistry are—Fig. 1. Crucibles, or pots, made either of earth, black lead, forged iron, or platina. They are used for roasting, calcination, and fusion. Crucibles. See the plate.

Fig. 2. Cucurbits, mattrasses, or bodies, which are glass, earthen, or metallic vessels, usually of the shape of an egg, and open at top. They serve the purposes of digestion, evaporation, &c. Cucurbits, or mattrasses.

Fig. 3. Retorts are globular vessels of earthen ware, glass, or metal, with a neck bended on one side. Some retorts have another neck or opening at their upper part, through which they may be charged, and the opening may be afterwards closed with a stopper. These are called tubulated retorts. Retorts.

 Fig. 4.

APPLICAT. OF HEAT.

Receivers.

Fig. 4. Receivers are veſſels, uſually of glaſs, of a ſpherical form, with a ſtraight neck, into which the neck of the retort is uſually inſerted. When any proper ſubſtance is put into a retort, and heated, its volatile parts paſs over into the receiver, where they are condenſed.

Alembic—of glaſs;

Fig. 5. The alembic is uſed for diſtillation when the products are too volatile to admit of the uſe of the laſt-mentioned apparatus. The alembic conſiſts of a body A, to which is adapted a head B. The head is of a conical figure, and has its external circumference or baſe depreſſed lower than its neck; ſo that the vapours which riſe, and are condenſed againſt its ſides, run down into the circular channel formed by its depreſſed part, from whence they are conveyed by the noſe or beak C, into the receiver D. This inſtrument is leſs ſimple than the retort, which certainly may be uſed for the moſt volatile products, if care be taken to apply a gentle heat on ſuch occaſions. But the alembic has its conveniencies. In particular, the reſidues of diſtillations may be eaſily cleared out of the body A; and, in experiments of ſublimation, the head is very convenient to receive the dry products, while the more volatile and elaſtic parts paſs over into the receiver.

—of metal.

Fig. 6, Is the drawing of an alembic commonly made in metal. The head is contained in a veſſel of cold water, to accelerate the condenſation; a method which is not ſo rational as that of cooling the receiver, becauſe the coldneſs of the head, in the former caſe, cauſes much of the vapour to fall again into the body.

Stills for ardent ſpirit.

Fig. 7, Repreſents the large ſtills uſed in the diſtillation of ardent ſpirits. Inſtead of uſing a refrigeratory or or receiver, the ſpirit is made to paſs through a ſpiral pipe, called the worm, which is immerſed in a tub of cold water. During its paſſage it is condenſed, and comes out at the lower extremity, E, of the pipe, in a fluid form.

Furnaces.

The beſt conſtruction of a furnace has not been well aſcertained from experience. There are facts which ſhew that a fire made on a grate near the bottom of a chimney, of equal width throughout, and open both above and below, will produce a more intenſe heat than any other furnace. What may be the limits for the height of the chimney, is not aſcertained from any preciſe trials; but thirty times its diameter would not probably be too high. It ſeems to be a diſadvantage to contract the diameter of a chimney, ſo as to make it ſmaller than that of the fire-place, when no other air is to go up the chimney than what has paſſed through the fire; and there is no proſpect of advantage to be derived from widening it.

Melting furnace.

Fig. 8, Exhibits the common ſmall furnace for melting. A is the aſh-hole, where the air enters. C is the fire-place, containing a covered crucible ſtanding on a ſupport of baked earth, which reſts on the grate. D is the paſſage into E the chimney. At D is a ſhallow crucible called a cupel, placed in the current of the flame; and at F is an earthen or ſtone cover, to be occaſionally taken off, for the purpoſe of ſupplying the fire with fuel.

Reverberatory furnace.

Fig. 9, Is the reverberatory furnace. A is the fire-place, B the dome and chimney, which is moveable. It ſerves to reflect the flames, and cauſes them to ſur-

APPLICAT. OF HEAT.

round the veſſel c, which is by that means more ſtrongly heated than otherwiſe.

Fuel.

Charcoal is the material moſt commonly uſed in furnaces. It produces an intenſe heat, without ſmoke; but it is conſumed very faſt. Coke, or charred pit-coal, produces a very ſtrong and laſting heat. Neither of theſe produce a ſtrong heat at a diſtance from the fire. Where the action of flame is required, wood or coal muſt be burned. Several inconveniencies attend the uſe of coal, as its fuliginous fumes, and its aptitude to ſtop the paſſage of air, by becoming fuſed. It is uſed however in the reverberatory furnaces of glaſs-houſes; and is the beſt material where veſſels are to be ſupplied with a great quantity of heat at no great intenſity, ſuch as in diſtilleries, &c.

Chemical bath.

In many operations where a moderate and regular heat is required, it is advantageous to uſe a bath, or to coat the veſſel intended to be heated. A chemical bath is uſually made by putting a quantity of water, ſand, or other fluid or pulverulent ſubſtance, into a metallic veſſel or pot, and immerſing the diſtilling veſſel in it. When the water or ſand is once heated, it prevents the ſudden changes in the intenſity of the fire from affecting the veſſel that contains the matter under examination. Chemical baths are made with water, ſand, iron filings, mercury, and with the fuſible compoſition of eight parts biſmuth, five lead, and three tin, which becomes fluid with a leſs heat than that of boiling water.

Coating.

Coating is chiefly intended to prevent glaſs veſſels from cracking by the ſudden variations of heat; and ſerves likewiſe to render them capable of preſerving their

their figure in higher degrees of heat than they could fuftain without it. The materials are clay and fine fand, well worked together into a pafte, and with the addition of fome hair, fuch as the bricklayers ufe. This is laid upon the veffel in fucceffive thin coatings.

Lutes.

The joints or clofures of veffels are made tight by compofitions called lutes. The clay and fand ufed for coating make a very good lute. In the diftillation of fubftances which are not corrofive, it is found convenient to clofe the junctures with paper, or linen, pafted on. Wet ftrips of bladder may alfo be ufed in thefe cafes. Slaked lime and the whites of eggs form a good lute, which fpeedily dries and becomes firm; but the compofition called fat lute is ufed when the vapours are of a corrofive and volatile nature. This is compofed of clay, firft made very dry and pulverized, and then beat together into a pafte with linfeed oil which has been boiled upon litharge, and is known in the fhops by the name of drying oil. Fat lute does not harden, but requires to be fecured on its place by ftrips of linen dipped in the lute made of lime and whites of eggs.

Fat lute.

Lamp.

The flame of a lamp with many fmall wicks may be ufed in diftillations that require a low heat.

Facility of making experiments.

An ingenious ftudent in chemiftry, when he has familiarifed himfelf with the firft principles, will foon perceive that there are few philofophical inquiries, if any, that require a large apparatus of furnace, or veffels. A tobacco pipe is a very ufeful crucible, in which a great number of operations may be performed in a common fire, efpecially if urged with a pair of good double bellows. An earthen pot, or iron ladle, will contain a fand-bath; and apothecaries phials, or Florence

 flafks,

APPLICAT. OF HEAT.

flafks, ferve very well for mattraffes. Chafing-difhes, or fmall iron ftoves, may be applied to ferve many ufeful purpofes. And the blow-pipe and fpirit-lamp, with a fet of very fmall retorts and receivers, may be adapted to the performance of almoft every part of experimental chemiftry.

Moveable furnaces.

The black-lead pots are very convenient for conftructing a variety of moveable furnaces. They may be cut without difficulty by a faw whofe teeth are fet wide; and very eafily admit of being fcraped, drilled, or ground with fand, to give them the requifite figure. In Dr. Lewis's conftruction, from whom the four following figures are taken *, the pots which are intended to be applied to each other, are ground flat upon a ftone, with a little fand; the holes are fawed with the common compafs-faw of the carpenters, and are made a little narrower externally than internally; by which means it is eafy to fit them with ftoppers made out of the broken pieces, that may be bought where the pots are fold. Three or four hoops of copper-wire, about the thicknefs of a crow-quill, and firft foftened by heating it red-hot, are faftened round the pots in the moft convenient places, to render them more durable by keeping their parts together, after they may have been cracked. A thin copper hoop ferves to fecure the place of junction of two pots.

Furnace for open fire.

Fig. 10, Reprefents a furnace for open fire formed by one pot. The lower fquare aperture is the door of the afh-pit, and the upper one the door of the fire-place, which, in the intentions this furnace is defigned for, is

* Lewis's Philofophical Commerce of Arts.

 kept

APPLICAT. OF HEAT.

kept ſhut. The charcoal is put in at the top, and ſupplied with air by one or more of the lower apertures; and the intenſity of the fire may in ſome meaſure be regulated by more or leſs cloſing of the apertures. If an iron pot, a ladle, or an old frying-pan, containing ſand, be put over this fire on three iron ſupporters, ſo as to leave room for the eſcape of the burned air from the fire, a bath will be formed, in which digeſtions, diſtillations, and other chemical operations, may be performed. The round hole in the bottom ſerves to inſert the nozzle of a pair of bellows, which, when the other apertures are ſtopped, converts it into a blaſt furnace.

Bath.

Moveable wind furnace.

Fig. 11, Is a wind furnace, formed by two pots applied mouth to mouth. An iron chimney compoſed of pieces, by which its length may be regulated ſo as to increaſe the draught at pleaſure, is put on the top. The crucible containing the ſubject matters is placed upon a circular piece of brick laid upon the grate, which prevents the cold air from immediately ſtriking the crucible, and endangering the breaking it. The charcoal is put through the fire place door, or larger aperture of the dome, or upper pot, which ſhould always be cloſed immediately after each ſupply of fuel. The two oppoſite holes in the upper part of the dome afford the conveniency of paſſing an iron rod through, for ſafely and commodiouſly lifting it when intenſely heated.

Reverberatory furnace.

Fig. 12, Is a furnace conſiſting of two pots, ſeparated by an iron hoop, in which an opening or door is cut. It ſerves for a reverberatory furnace for diſtilling with retorts of earthen ware or coated glaſs. The bottom

APPLICAT. OF HEAT.

bottom of the diftilling veffel refts on two bars laid acrofs within the lower pot. If the grate of this furnace be occafionally changed for a larger, which may be placed near the edge of the lower pot, a muffle, or fmall earthen oven, may be placed in the midft of the fire, with its mouth oppofite the hole in the iron hoop. In this may be performed all proceffes that require the admiffion of air, and frequent infpection, fuch as affays, enamelling, &c.

Moveable blaft furnace.

Fig. 13, Is an improved blaft furnace. The pot which contains the fuel for this purpofe, has a number of holes bored at fmall diftances, in fpiral lines, all over it, from the bottom up to fuch an height as it is defigned the fuel fhall reach. The crucible is placed upon a proper fupport in the bottom; and the holes are made, not in a perpendicular direction to it, but oblique, that the ftreams of air forced in through them may but juft touch it: by this means the crucible is in no danger of being cracked by the blaft, and the impelled heat plays in a kind of fpiral upon its furface. The lower pot receives this perforated pot to fuch a depth that all its holes hang in the cavity; which cavity having no other outlet than the aperture for the bellows, the air blown in through this aperture neceffarily diftributes itfelf through the perforations of the inner pot. Both pots may be of the largeft fize, the external narrow part of the inner falling into the wide mouth of the outer. It wants no addition to its height; but, on the contrary, will be more commodious in regard to the infpection and taking out of the crucible, if all the part above where the fuel reaches be fawed away. The moft convenient cover for it, is an iron plate with a round

round hole in the middle, and a handle projecting at one fide for lifting it. (Letter A.) APPLICAT. OF HEAT.

The force of the fire being thus in a great meafure 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 furnace are of no great heat, and permit the operator to approach without incommoding him.

Blow-pipe.

Every effect of the moſt violent heat of furnaces may be produced by the flame of a candle, or lamp, urged upon a ſmall particle of any ſubſtance by the blow-pipe. This inſtrument is ſold by the ironmongers; and conſiſts merely of a braſs pipe, about one eighth of an inch diameter at one end, and the other tapering to a much leſs ſize, with a very ſmall perforation for the wind to eſcape. The ſmaller end is bended on one ſide. For philoſophical, or other nice purpoſes, the blow-pipe is provided with a bowl, or enlargement, B, (fig. 14) in which the vapours of the breath are condenſed and detained; and alſo with three or four ſmall nozzles, with different apertures, to be ſlipped on the ſmaller extremity. Theſe are of uſe when larger or ſmaller flames are to be occaſionally uſed; becauſe a larger flame requires a larger aperture, in order that the air may effectually urge it upon the matter under examination.

Artifice of blowing through the pipe.

There is an artifice in the blowing through this pipe, which is more difficult to deſcribe than to acquire. The effect intended to be produced is a continual ſtream of air for many minutes, if neceſſary, without ceaſing. This is done by applying the tongue to the roof of the mouth,

APPLICAT. OF HEAT.

mouth, fo as to interrupt the communication between the mouth and the paffage of the noftrils: by which means the operator is at liberty to breathe through the noftrils, at the fame time that, by the mufcles of the lips, he forces a continual ftream of air from the anterior part of the mouth through the blow-pipe. When the mouth begins to be empty, it is replenifhed by the lungs in an inftant; while the tongue is withdrawn from the roof of the mouth, and replaced again in the fame manner as in pronouncing the monofyllable tut. In this way the ftream may be continued for a long time without any fatigue, if the flame be not urged too impetuoufly; and even in this cafe no other fatigue is felt than that of the mufcles of the lips.

Flame urged by the blow-pipe.

A wax-candle of a moderate fize, but thicker wick than they are ufually made with, is the moft convenient for occafional experiments; but a tallow-candle will do very well. The candle fhould be fnuffed rather fhort, and the wick turned on one fide towards the object, fo that a part of it fhould lie horizontal. The ftream of air muft be blown along this horizontal part as near as may be without ftriking the wick. If the flame be ragged and irregular, it is a proof that the hole is not round or fmooth; and if the flame have a cavity through it, the aperture of the pipe is too large. When the hole is of a proper figure, and duly proportioned, the flame confifts of a neat luminous blue cone, furrounded by another flame of a more faint and indiftinct appearance. The ftrongeft heat is at the point of the inner flame.

The fubject to be heated.

The body intended to be acted on by the blow-pipe, ought not to exceed the fize of a pepper-corn. It may be laid

laid upon a piece of clofe-grained well-burned charcoal, unlefs it be of fuch a nature as to fink into the pores of that fubftance, or to have its properties affected by its inflammable quality. Such bodies may be placed in a fmall fpoon made of pure gold, or filver, or platina.

Advantages of the blow-pipe:

Many great advantages may be derived from the ufe of this fimple and valuable inftrument. Its fmallnefs, which renders it fuitable to the pocket, is no inconfiderable recommendation. The moft expenfive materials, and the minuteft fpecimens of bodies, may be ufed in thefe experiments; and the whole procefs, inftead of being carried on in an opake veffel, is under the eye of the obferver from beginning to end. It is true that very little can be determined in this way concerning the quantities of products; but in moft cafes a knowledge of the contents of any fubftance is a great acquifition, which is thus obtained in a very fhort time, and will at all events ferve to fhew the beft and leaft expenfive way of conducting proceffes with the fame matters in the larger way.

—its ufe rendered eafy by bellows.

The blow-pipe * has defervedly of late years been confidered as an effential inftrument in a chemical laboratory; and feveral attempts have been made to facilitate its ufe by the addition of bellows, or fome other equivalent inftrument. Thefe are doubtlefs very convenient, though they render it lefs portable for mineralogical refearches. It will not here be neceffary to enter into any defcription of a pair of double bellows fixed under a table, and communicating with a blow-pipe

* See Magellan's edition of Cronftedt's Mineralogy, or Bergmann's Chemical Effays.

which

which paſſes through the table. Smaller bellows, of a portable ſize for the pocket, have been made for the ſame purpoſe. The ingenious chemiſt will find no great difficulty in adapting a bladder to the blow-pipe, which, under the preſſure of a board, may produce a conſtant ſtream of air; and may be repleniſhed, as it becomes empty, by blowing into it with bellows, or the mouth, at another aperture furniſhed with a valve opening inwards.

Blow-pipe with vital air.

The chief advantage theſe contrivances have over the common blow-pipe is, that they may be filled with vital or dephlogiſticated air, which increaſes the activity of combuſtion to an aſtoniſhing degree.

CHAP.

CHAP. V.

CONCERNING THE METHODS OF MAKING EXPERIMENTS ON BODIES IN THE FLUID AND IN THE AERIFORM STATE.

PROCESSES WITHOUT HEAT.

FROM the preceding chapter, the methods of conducting proceſſes, in which conſiderable heat is required, may be eaſily underſtood. Little need be ſaid concerning the manner of making experiments with fluid bodies in the common temperature of the atmoſphere. Baſons, cups, phials, mattraſſes, and other ſimilar veſſels, form the whole apparatus required for the purpoſe of containing the matters intended to be put together; and no other precaution or inſtruction is required, than to uſe a veſſel of ſuch materials as ſhall not be corroded or acted upon by its contents, and of ſufficient capacity to admit of any ſudden expanſion, or frothing of the fluid, if expected. This veſſel muſt be placed in a current of air, if noxious fumes ariſe, in order that theſe may be blown from the operator.

Apparatus for denſe fluids.

The method of making experiments with permanently elaſtic fluids or air, though ſimple, is not ſo obvious. We live immerſed in an atmoſphere not greatly differing in denſity from theſe fluids; which are not, for that reaſon, ſufficiently ponderous to be detained in open veſſels by their weight. Their remarkable levity, however, affords a method of confining them, by means of other denſer fluids. Dr. Prieſtley, whoſe labours have ſo far exceeded thoſe of his predeceſſors and cotemporaries, both in extent and importance, that he may

— for elaſtic fluids.

PROCESSES WITHOUT HEAT.

Apparatus for experiments with elastic fluids.

may with juftice be ftyled the father of this important branch of natural philofophy, ufes the following apparatus.

Fig. 15. A reprefents a wooden veffel, or tub; K, K, K, is a fhelf fixed in the tub. When this apparatus is ufed, the tub is to be filled with water to fuch an height, as to rife about one inch above the upper furface of the fhelf. B, C, F, are glafs jars inverted with their mouths downwards, which reft upon the fhelf. If thefe, or any other veffels open only at one end, be plunged under the water, and inverted after they are filled, they will remain full, notwithftanding their being raifed out of the water, provided their mouths be kept immerfed; for in this cafe the water is fuftained by the preffure of the atmofphere in the fame manner as the mercury in the barometer. It may without difficulty be imagined, that if common air, or any other fluid refembling common air in lightnefs and elafticity, be fuffered to enter thefe veffels, it will rife to the upper part, and the furface of the water will fubfide. If a bottle, a cup, or any other veffel in that ftate which is ufually called empty, though really full of air, be plunged into the water with its mouth downwards, fcarcely any water will enter, becaufe its entrance is oppofed by the elafticity of the included air; but if the veffel be turned up, it immediately fills, and the air rifes in one or more bubbles to the furface. Suppofe this operation to be performed under one of the jars which are filled with water: the air will afcend as before; but, inftead of efcaping, it will be detained in the upper part of the jar. In this manner, therefore, we fee that air may be emptied out of one veffel into another, by an inverted pouring, in which

which the air is made to afcend from the lower to the upper veffel, in which the experiments are performed, by the action of the weightier fluid, exactly fimilar to the common pouring of denfer fluids, detained in the bottoms of open veffels, by the fimple action of gravity. When the receiving veffel has a narrow neck, the air may be poured through a glafs funnel, H.

PROCESSES WITH ELASTIC FLUIDS.

Apparatus for experiments with elaftic fluids.

C (fig. 15) is a glafs body or bottle, whofe bottom is blown very thin, that it may fupport the heat of a candle fuddenly applied, without cracking. In its neck is fitted, by grinding, a tube D, curved nearly in the form of the letter s. This kind of veffel is very ufeful in various chemical operations, for which it will be convenient to have them of feveral fizes. In the figure, the body c is reprefented as containing a fluid, in the act of combining with a fubftance that gives out air, which paffes through the tube into the jar B, under whofe mouth the other extremity of the tube is placed. At E is a fmall retort of glafs or earthen ware, whofe neck being plunged in the water, beneath the jar F, is fuppofed to emit the elaftic fluid, extricated from the contents of the retort, which is received in the jar.

Body and tube.

When any thing, as a gallipot, is to be fupported at a confiderable height within a jar, it is convenient to have fuch wire ftands as are reprefented fig. 16. Thefe anfwer better than any other, becaufe they take up but little room, and are eafily bended to any figure or height.

Stand or fupport of wire.

In order to expel air from folid fubftances by means of heat, a gun-barrel, with the touch-hole fcrewed up and riveted, may be ufed inftead of an iron retort.

Gun-barrel.

APPARATUS FOR ELASTIC FLUIDS

The fubject may be put in the chamber of the barrel, and the reft of the bore may be filled with dry fand, that has been well burned, to expel whatever air it might have contained. The flem of a tobacco-pipe, or a fmall glafs tube, being luted in the orifice of the barrel, the other extremity muft be put into the fire, that the heat may expel the air from its contents. This air will of courfe pafs through the tube, and may be received under an inverted veffel, in the ufual manner.

Phials with quickfilver.

But the moft accurate method of procuring air from feveral fubftances, by means of heat, is, to put them, if they will bear it, into phials full of quickfilver, with the mouths inverted in the fame, and then throw the focus of a burning lens or mirror upon them. For this purpofe their bottoms fhould be round, and very thin, that they may not be liable to fly with the fudden application of heat. The body c anfwers this purpofe very well.

Burning lens, or mirror.

Apparatus with mercury.

Many kinds of air combine with water, and therefore require to be treated in an apparatus in which quickfilver is made ufe of. This fluid being very ponderous, and of confiderable price, it is an object of convenience as well as œconomy, that the trough and veffels fhould be fmaller than when water is ufed.

Combuftion of air.

When trial is to be made of any kind of air, whether it be fit for maintaining combuftion, the air may be put in a long narrow glafs veffel, whofe mouth being carefully covered, may be turned upward. A bit of wax candle being then faftened to the end of a wire, which is bended fo that the flame of the candle may be upper-

uppermoſt, is to be let down into the veſſel, which muſt be kept covered till the inſtant of plunging the lighted candle in the air. APPARATUS FOR ELASTIC FLUIDS.

Where the change of dimenſions, which follows from the mixture of ſeveral kinds of air, is to be aſcertained, a graduated narrow cylindrical veſſel may be made uſe of. The graduations may be made by pouring in ſucceſſive equal meaſures of water into this veſſel, and marking its ſurface at each addition. The meaſure may be afterwards uſed for the different kinds of air; and the change of dimenſions will be ſhewn by the riſe or fall of the mercury, or water, in the graduated veſſel. The purity of common air being determinable by the diminution produced by the addition of nitrous air, theſe tubes have been called eudiometer tubes. There are inſtruments called eudiometers, which conſiſt of an aſſemblage of parts adapted to the due mixture of theſe airs, and the accurate meaſurement of the change of bulk they undergo. Meaſuring tubes. Eudiometers.

There are ſome ſubſtances, more eſpecially powders, which cannot conveniently be put in a phial, or paſſed through a fluid. When air is to be extricated from, or added to, theſe, there is no better method than to place them on a ſtand under the receiver of the air-pump, and exhauſt the common air, inſtead of excluding it by water or mercury. This proceſs requires a good air-pump and careful management, otherwiſe the common air will not be well excluded. Management of powders.

It is frequently an intereſting object to paſs the electric ſpark through different kinds of air, either alone or mixed together. In this caſe a metallic wire may be faſtened in the upper end of a tube, and the ſparks, Electric ſpark.

APPARATUS FOR ELASTIC FLUIDS.

Electricity applied.

or ſhock, may be paſſed through this wire to the mercury or water uſed to confine the air. If there be reaſon to apprehend that an expanſion in the air may remove the mercury or water beyond the ſtriking diſtance, another wire may be thruſt up to receive the electricity, or two wires may be cemented into oppoſite holes in the ſides of an hermetically ſealed tube.

Holes drilled in glaſs.

Holes may be made in glaſs for this and other chemical uſes, by a drill of copper, or ſoft iron, with emery and water; and, where this inſtrument is wanting, a ſmall round file with water will cut a notch in ſmall veſſels, ſuch as phials or tubes, though with ſome danger of breaking them. In ſome electrical experiments of the kind here mentioned, there is reaſon to expect a fallacious reſult from the wires being burned by the exploſion, or ſpark. For this reaſon the electricity may be made to paſs through the legs of a ſyphon, containing the air which is under conſideration in the upper part of its curvature. One of the veſſels in which the legs of the ſyphen reſt, muſt therefore be inſulated; and if any watery fluid be uſed to confine the air, it is generally ſuppoſed that no combuſtion takes place.

Impregnation of water;

The proceſs of impregnating water with any aerial fluid it will combine with, does not require any particular apparatus, but may be performed with ſuch utenſils as are every where to be met with. The moſt uſual operation of this kind is that of impregnating water with fixed air; which may be done in the following manner. The quart bottle c, fig. 17, is filled with water, and inverted into the baſon F, which likewiſe contains a little water. The inverſion may be

—with fixed air.

eaſily

APPARATUS FOR ELASTIC FLUIDS.

eafily managed, without any of the contents of the bottle efcaping, if its orifice be covered with a card, to be withdrawn after the immerfion. A is a half-pint phial, into which broken pieces of marble or chalk are put; and upon them is poured as much water, rendered very acid by a mixture of oil of vitriol, as may fill the bottle two-thirds. B is a bladder, whofe neck is tied faft round a perforated cork of a tapering figure. After the effervefcence of the chalk and the acid has begun, the cork is to be thruft into the neck of the phial A, the bladder being previoufly emptied by preffure. Fixed air will efcape from the chalk, and inflate the bladder. When this laft is full, it muft be difengaged from the bottle, and the bended tube E muft be thruft into the orifice of its cork. The aperture of the tube being then placed beneath the mouth of the bottle C, it is eafy to difcharge the aerial contents of the bladder by preffure into this laft. Agitation of the bottle C, without withdrawing its neck out of the water, increafes the contact of the air and water, by dividing them into fmall parts, and by that means caufes the abforption to take place in a few feconds. Two or three repetitions of this procefs impregnate the water fo fully, that it will abforb no more in this way. The Pyrmont water is of this kind.

The ufe of the bladder, in this operation, is only to prevent any of the fluid contents of the bottle A from paffing into the bottle C, which would happen in the violent ftate of ebullition, if the tube E were to pafs directly from the bottle A to C. The manipulation is fimpler if the bladder have two holes at its oppofite

APPARATUS FOR ELASTIC FLUIDS.

ends, the one containing a cork, conſtantly kept in the neck of the bottle A, and the other faſtened round the tube E, which then remains conſtantly beneath the mouth of C; and the air is preſſed up as occaſion may demand. See fig. 18.

Dr. Nooth's apparatus.

When habitual uſe is made of water impregnated with fixed air, the apparatus of Dr. Nooth is very effectual and convenient. It conſiſts of three glaſs veſſels (fig. 19). The lower veſſel C contains the effervescent materials: it has a ſmall orifice at D, ſtopped with a ground ſtopper, at which an additional ſupply of either acid, or water, or chalk, may be occaſionally introduced. The middle veſſel B is open both above and below. Its inferior neck is fitted by grinding into the neck H of the lower veſſel. In the former is a glaſs valve, formed by two pieces of tube, and a lens, which is moveable, between them, as repreſented in fig. 20. This valve opens upwards, and ſuffers the air to paſs; but the water cannot return through the tubes, partly becauſe the orifice is capillary, and partly becauſe the flat lens covers the hole. The middle veſſel is furniſhed with a cock E, to draw off its contents. The upper veſſel A is fitted, by grinding, into the upper neck of the middle veſſel. Its inferior part conſiſts of a tube, that paſſes almoſt as low as the centre of the middle veſſel. Its upper orifice is cloſed by a ground ſtopper F. When this apparatus is to be uſed, the effervefcent materials are put into the lower veſſel; the middle veſſel is filled with pure water, and put in its place; and the upper veſſel is nearly ſtopped, and likewiſe put in its place. The conſequence is,

 that

that the fixed air, paffing through the valve at H, ascends into the upper part of the middle veffel B, where, by its elafticity, it re-acts on the water, and forces part up the tube into the veffel A; part of the common air, in this laft, being compreffed, and the reft efcaping by the ftopper, which is made of a conical figure, that it may be eafily raifed. As more fixed air is extricated, more water rifes, till at length the water in the middle veffel falls below the lower orifice of the tube. Fixed air then paffes through the tube into the upper veffel, and expels more of the common air by raifing the ftopper. In this fituation the water in both veffels, being in contact with a body of fixed air, becomes ftrongly impregnated with that fluid, after a certain time. This effect may be haftened by taking off the middle and upper veffels together, and agitating them.

APPARATUS FOR ELASTIC FLUIDS.

Dr. Nooth's apparatus:

The valve is the moft defective part of this apparatus: for the capillary tube does not admit the air through, unlefs there be a confiderable quantity condenfed in the lower veffel: and the condenfation has, in fome inftances, burft the veffel.

—its valve defective.

Modern difcoveries, refpecting bodies in the aeriform ftate, have produced feveral capital improvements in the veffels ufed for diftillation. It was common with the earlier chemifts to make a fmall hole in the upper part of their retorts, that the elaftic vapours might efcape, which would otherwife have burft the veffels. By this means they loft a very confiderable part of their products. Fig. 21, is an apparatus of veffels*, in

Improvements in diftillation.

* Prieftley, III.

VESSELS FOR DISTILLING.

Combination of receivers.

in which all the products may be examined. A is a mattrafs, which communicates with the receiver B, by a tube that reaches very near the bottom of the latter. The upper part of this receiver communicates in the fame manner with the fecond receiver C, by a tube reaching nearly to the bottom of C. In like manner C communicates with D, and from D proceeds a recurved tube, which may be inferted beneath an inverted veffel of water, or mercury. It is evident, in this apparatus, that whatever volatile matter efcapes from the veffel A, by heat or otherwife, will either be condenfed in B, C, or D; and that the aerial products will pafs through the whole fet, and through the recurved tube, into the inverted veffel. Thefe receivers may be more or lefs numerous, according to circumftances; and the volatile products may be condenfed in, or made to pafs through, water, oil, or any other fluids placed in either of the receivers. The tubes may be either fitted in with cork and cement; or, which is better, but more expenfive, by grinding. Small veffels of this kind form a convenient interruption in the recurved tube, paffing from a bottle containing matters that give out air, as they are preferable in clofenefs and neatnefs to a bladder.

Improved receiver.

Fig. 22, Exhibits an improvement in the receiver in diftillation*. A is the retort. B an intermediate veffel, called an adopter, which is only occafionally ufed. C the receiver, having two necks; one at D, inferted into a bottle which receives the products which are

* By Mr. Woulfe. Prieftley, III.

ufually

ufually condenfed in the receiver; and the other, at E, tranfmits the more volatile or aeriform products into a bafon G, containing water; beneath the furface of which the extremity of the neck E is plunged. It is obvious that this apparatus is more particularly ufeful when the products are fuch as combine with the fluids in G, and would otherwife efcape; and it is hardly neceffary to obferve, that a bottle, or other convenient veffel, may be fubftituted inftead of the bafon G.

Remedy againft abforption.

It often happens in chemical proceffes, from the irregularity of the heat, or from other circumftances, that the condenfation is more rapid, in proportion to the fupply of vapour, at fome periods of the fame operation than at others. Whenever this takes place, the elafticity of the vapours will not be equal to the external preffure of the air; and if any orifice of the veffels, which are in other refpects clofed, be plunged in water, or any other fluid, this laft will be preffed into the veffels. The remedy for this inconvenience is, to plunge the neck of the veffel to no greater depth in the water, than that the fall of the water, in the receiving veffel, may leave the orifice open for the admiffion of air, before the water has rifen high enough above the orifice to reach the contents of the veffels. This effect is increafed by making the neck large, in proportion to the diameter of the veffel which contains the water. Thus, if the neck E be made large, and the water from the bafon G fhould, by a rapid condenfation in C, be forced up the neck, the furface of the water in G will fall fo much as to leave the lower orifice of E uncovered, before any confiderable rife can take

DISTILLATION.

Remedy againſt abſorption:

take place; but if F were narrower, its whole capacity would be filled, and the water would run over into C before the fall in G would be ſufficient to uncover the orifice of F, and reſtore the equilibrium, by admitting common air. This obſervation applies to all chemical veſſels, and is in no caſe more eſſential than when the neck of a ſimple retort is plunged in water contained in a receiver.

—of Chaptal.

The above contrivance, which is Mr. Babington's, cannot very conveniently be applied to the apparatus fig. 21, in which nevertheleſs the condenſation of elaſtic matter in the retort might occaſion a diſagreeable return of the fluids from the reſpective bottles in ſucceſſion Chaptal remedies this by a very ſimple expedient. He has the tube of communication between A and B rather too ſhort to reach the liquid in B; and through the bottom or upper part of this inverted receiver B he paſſes a ſmall tube open at both ends, and plunged into the liquid. This communication with the external air has no perceptible effect, as far as relates to any eſcape of the vapours; though it effectually remedies the conſequences of abſorption.

CHAP.

CHAP. VI.

CONCERNING THE BALANCE AND WEIGHTS, WITH A COMPARATIVE TABLE OF THE VARIOUS WEIGHTS MADE USE OF IN EUROPE.

THE BALANCE.

THE beginning and end of every exact chemical process consist in weighing. With imperfect instruments this operation will be tedious and inaccurate: but, with a good balance, the results will be satisfactory; and much time, which is so precious in experimental researches, will be saved. I have not, therefore, thought it improper to devote a whole chapter to this general and important subject; by the help of which, if attentively considered, the chemical student may learn to distinguish a good instrument, or correct the errors of a bad one.

Balance described.

The balance is a lever, whose axis of motion is formed with an edge like that of a knife; and the two dishes at its extremities are hung upon edges of the same kind. These edges are first made sharp, and then rounded with a fine hone, or a piece of buff leather. The excellence of the instrument depends, in a great measure, on the regular form of this rounded part. When the lever is considered as a mere line, the two outer edges are called points of suspension, and the inner the fulcrum. The points of suspension are supposed to be at equal distances from the fulcrum, and to be pressed with equal weights when loaded.

Points of suspension. Fulcrum.

1. If

THE BALANCE.
Propofitions.

1. If the fulcrum be placed in the center of gravity of the beam, and the three edges lie all in the fame right line, the balance will have no tendency to one pofition more than another; but will reft in any pofition it may be placed in, whether the fcales be on or off, empty or loaded.

2. If the center of gravity of the beam, when level, be immediately above the fulcrum, it will overfet by the fmalleft action; that is, the end which is loweft will defcend: and it will do this with more fwiftnefs the higher the center of gravity, and the lefs the points of fufpenfion are loaded.

3. But if the center of gravity of the beam be immediately below the fulcrum, the beam will not reft in any pofition but when level; and, if difturbed from that pofition, and then left at liberty, it will vibrate, and at laft come to reft on the level. Its vibrations will be quicker, and its horizontal tendency ftronger, the lower the center of gravity, and the lefs the weight upon the points of fufpenfion.

4. If the fulcrum be below the line joining the points of fufpenfion, and thefe be loaded, the beam will overfet, unlefs prevented by the weight of the beam tending to produce an horizontal pofition; as in § 3. In this laft cafe, fmall weights will equilibrate, as in § 3; a certain exact weight will reft in any pofition of the beam, as in § 1; and all greater weights will caufe the beam to overfet, as in § 2. Money fcales are often made this way, and will overfet with any confiderable load.

Money fcales.

5. If the fulcrum be above the line joining the points of fufpenfion, the beam will come to the horizontal

zontal position, unless prevented by its own weight, as in § 2. If the center of gravity of the beam be nearly in the fulcrum, all the vibrations of the loaded beam will be made in times nearly equal, unless the weights be very small, when they will be slower. The vibrations of balances are quicker, and the horizontal tendency stronger, the higher the fulcrum. Propositions.

6. If the arms of a balance be unequal, the weights in equipoise will be unequal in the same proportion. It is a severe check upon a workman to keep the arms equal, while he is making the other adjustments in a strong and inflexible beam.

7. The equality of the arms of a balance is of use, in scientific pursuits, chiefly in the making of weights by bisection. A balance with unequal arms will weigh as accurately as another of the same workmanship with equal arms, provided the standard weight itself be first counterpoised, then taken out of the scale, and the thing to be weighed be put into the scale, and adjusted against the counterpoise. Or, when proportional quantities only are considered, as in chemical and other philosophical experiments, the bodies and products under examination may be weighed against the weights, taking care always to put the weights in the same scale. For then, though the bodies may not be really equal to the weights, yet their proportions amongst each other will be the same as if they had been accurately so.

Weighing with a balance which is not equibrachial.

8. But though the equality of the arms may be well dispensed with, yet it is indispensably necessary that their relative lengths, whatever they may be, should continue invariable. For this purpose, it is necessary either

THE BALANCE.

either that the three edges be all truly parallel, or that the points of ſuſpenſion and ſupport ſhould be always in the ſame part of the edge. This laſt requiſite is the moſt eaſily obtained.

Conſtruction. The balances made in London are uſually conſtructed in ſuch a manner, that the bearing parts form notches in the other parts of the edges; ſo that the ſcales being ſet to vibrate, all the parts naturally fall into the ſame bearing. The balances made in the country have the fulcrum edge ſtraight, and confined to one conſtant bearing by two ſide plates. But the points of ſuſpenſion are referred to notches in the edges, like the London balances. The balances here mentioned, which come from the country, are incloſed in a ſmall iron japanned box; and are to be met with at the Birmingham and Sheffield warehouſes, though leſs frequently than ſome years ago; becauſe a pocket contrivance for weighing guineas and half guineas has got poſſeſſion of the market. They are, in general, well made and adjuſted, turn with the twentieth of a grain when empty, and will ſenſibly ſhew the tenth of a grain, with an ounce in each ſcale. Their price is from five ſhillings to half-a-guinea; but thoſe which are under ſeven ſhillings have not their edges hardened, and conſequently are not durable. This may be aſcertained by the purchaſer, by paſſing the point of a penknife acroſs the ſmall piece which goes through one of the end boxes; if it makes any mark or impreſſion, the part is ſoft.

The turn. 9. If a beam be adjuſted ſo as to have no tendency to any one poſition, as in § 1, and the ſcales be equally loaded; then, if a ſmall weight be added in one of the ſcales, fcales, that balance will turn, and the points of fufpenfion will move with an accelerated motion, fimilar to that of falling bodies; but as much flower in proportion, very nearly, as the added weight is lefs than the whole weight borne by the fulcrum.

Propofitions.

10. The ftronger the tendency to an horizontal pofition in any balance, or the quicker its vibrations, § § 3, 5, the greater additional weight will be required to caufe it to turn or incline to any given angle. No balance therefore can turn fo quick as the motion deduced in § 9. Such a balance as is there defcribed, if it were to turn with the ten thoufandth part of the weight, would move at quickeft ten thoufand times flower than a falling body; that is, the difh containing the weight, inftead of falling through fixteen feet in a fecond of time, would fall through only two hundredth parts of an inch, and it would require four feconds to move through one third part of an inch: confequently, all accurate weighing muft be flow. If the indexes of two balances be of equal lengths, that index which is connected with the fhorter balance will move proportionally quicker than the other. Long beams are the moft in requeft, becaufe they are thought to have lefs friction. This is doubtful: but the quicker angular motion, greater ftrength, and lefs weight, of a fhort balance, are certain advantages.

Accurate weighing is flow.

Long beams.

11. Very delicate balances are not only ufeful in nice experiments, but are likewife much more expeditious than others in common weighing. If a pair of fcales, with a certain load, be barely fenfible to the one-tenth of a grain, it will require a confiderable time to afcertain the weight to that degree of accuracy,

becaufe

THE BALANCE. Propofitions.

becaufe the turn muft be obferved feveral times over; and is very fmall. But if no greater accuracy were required, and fcales were ufed which would turn with the hundredth of a grain, a tenth of a grain more or lefs would make fo great a difference in the turn, that it would be feen immediately.

12. If a balance be found to turn with a certain addition, and is not moved by any fmaller weight, a greater fenfibility may be given to that balance, by producing a tremulous motion in its parts. Thus, if the edge of a blunt faw, a file, or other fimilar inftrument, be drawn along any part of the cafe or fupport of a balance, it will produce a jarring, which will diminifh the friction on the moving parts fo much, that the turn will be evident with one third or one fourth of the addition that would elfe have been required. In this way a beam which would barely turn by the addition of the tenth of a grain, will turn with the thirtieth or fortieth of a grain.

13. A balance whofe horizontal tendency depends only on its own weight, as in § 3, will turn with the fame addition, whatever may be the load: except fo far as a greater load will produce a greater friction.

14. But a balance whofe horizontal tendency depends only on the elevation of the fulcrum, as in § 5, will be lefs fenfible the greater the load; and the addition requifite to produce an equal turn will be in proportion to the load itfelf.

15. In order to regulate the horizontal tendency in fome beams, the fulcrum is placed below the points of fufpenfion, as in § 4, and a fliding weight is put upon the cock or index; by means of which the centre of gravity

gravity may be raifed or depreffed. This is an ufeful contrivance. THE BALANCE.

16. Weights are made by a fubdivifion of a ftandard weight. If the weight be continually halved, it will produce the common pile, which is the fmalleft poffible number for weighing between its extrêmes, without placing any weight in the fcale with the body under examination. Granulated lead is a very convenient fubftance to be ufed in this operation of halving, which however is very tedious. The readieft way to fubdivide fmall weights, confifts in weighing a certain quantity of fmall wire, and afterwards cutting it into fuch parts, by meafure, as are defired. Or the wire may be wrapped clofe round two pins, and then cut afunder with a knife. By this means it will be divided into a great number of equal lengths, or fmall rings. The wire ought to be fo thin, as that one of thefe rings may barely produce a fenfible effect on the beam. If any quantity (as, for example, a grain) of thefe rings be weighed, and the number then reckoned, the grain may be fubdivided in any proportion, by dividing that number, and making the weights equal to as many of the rings as the quotient of the divifion denotes. Then, if 750 of the rings amounted to a grain, and it were required to divide the grain decimally, downwards, $\frac{9}{10}$ would be equal to 675 rings, $\frac{8}{10}$ would be equal to 600 rings, $\frac{7}{10}$ to 525 rings, &c. Small weights may be made of thin leaf brafs. Jewellers foil is a good material for weights below the $\frac{1}{10}$ of a grain, as low as to the $\frac{1}{100}$ of a grain; and all lower quantities may be either eftimated by the pofition of the index, or fhewn by actually counting

Sets of weights.

Common pile.

Bifection.

Wire rings.

ing

THE BALANCE.

ing the rings of wire, whofe value has been determined.

Number of weights required to form a fet.

17. In philofophical experiments, it will be found very convenient to admit no more than one dimenfion of weight. The grain is of that magnitude as to deferve the preference. With regard to the number of weights the chemift ought to be provided with, writers have differed according to their habits and views. Mathematicians have computed the leaft poffible number with which all weights, within certain limits, might be afcertained; but their determination is of little ufe, becaufe, with fo fmall a number, it muft often happen, that the fcales will be heavily loaded with weights, on each fide, put in with a view only to determine the difference between them. It is not the leaft poffible number of weights which it is neceffary an operator fhould buy to effect his purpofe, that we ought to enquire after, but the moft convenient number for obtaining the refults with accuracy and expedition. The error of adjuftment is the leaft poffible, when only one weight is in the fcale; that is, a fingle weight of five grains is twice as likely to be true, as two weights, one of three, and the other of two grains, put into the difh to fupply the place of the fingle five, becaufe each of thefe laft has its own probability of error in adjuftment. But, fince it is as inconfiftent with convenience to provide a fingle weight, as it would be to have a fingle character for every number; and as we have nine characters, which we ufe in rotation, to exprefs higher values according to their pofition; it will be found very ferviceable to make the fet of weights correfpond with our numerical fyftem.

fyftem. This directs us to the fet of weights, as follows: 1000 grains, 900 g. 800 g. 700 g. 600 g. 500 g. 400 g. 300 g. 200 g. 100 g. 90 g. 80 g. 70 g. 60 g. 50 g. 40 g. 30 g. 20 g. 10 g. 9 g. 8 g. 7 g. 6 g. 5 g. 4 g. 3 g. 2 g. 1 g. $\frac{9}{10}$ g. $\frac{8}{10}$ g. $\frac{7}{10}$ g. $\frac{6}{10}$ g. $\frac{5}{10}$ g. $\frac{4}{10}$ g. $\frac{3}{10}$ g. $\frac{2}{10}$ g. $\frac{1}{10}$ g. $\frac{9}{100}$ g. $\frac{8}{100}$ g. $\frac{7}{100}$ g. $\frac{6}{100}$ g. $\frac{5}{100}$ g. $\frac{4}{100}$ g. $\frac{3}{100}$ g. $\frac{2}{100}$ g. $\frac{1}{100}$. With thefe the philofopher will always have the fame number of weights in his fcales as there are figures in the number expreffing the weights in grains.

THE BALANCE. Decimal fet of weights.

Thus 742.5 grains will be weighed by the weights 700, 40, 2, and $\frac{5}{10}$.

Account of fome balances.

I fhall conclude this chapter with an account of fome balances I have feen or heard of, and annex a table of the correfpondence of weights of different countries.

The balance of Mufchenbroek:

Mufchenbroek, in his Cours de Phyfique (French tranflation, Paris, 1769), tom. ii. p. 247, fays, he ufed an ocular balance of great accuracy, which turned (trebuchoit) with $\frac{1}{40}$ of a grain. The fubftances he weighed were between 200 and 300 grains. His balance, therefore, weighed to the $\frac{1}{12000}$ part of the whole; and would afcertain fuch weights truly to four places of figures.

—of Bolton.

In the Philofophical Tranfactions, vol. lxvi. p. 509, mention is made of two accurate balances of Mr. Bolton; and it is faid that one would weigh a pound, and turn with $\frac{1}{10}$ of a grain. This, if the pound be avoirdupois, is $\frac{1}{70000}$ of the weight; and fhews that the balance could be well depended on to four places of figures, and probably to five. The other weighed half an ounce, and turned with the $\frac{1}{100}$ of a grain. This is the $\frac{1}{24000}$ of the weight.

Balance of Mr. Read:

In the same volume, p. 511, a balance of Mr. Read's is mentioned, which readily turned with less than one pennyweight, when loaded with 55 pounds, before the Royal Society; but very distinctly turned with four grains when tried more patiently. This is about the $\frac{1}{96000}$ part of the weight; and therefore this balance may be depended on to five places of figures.

—of Mr. Whitehurst:

Also, p. 576, a balance of Mr. Whitehurst's weighs one pennyweight, and is sensibly affected with the $\frac{1}{2000}$ of a grain. This is $\frac{1}{48000}$ part of the weight.

—of the Author;

I have a pair of scales of the common construction, § 8, made expressly for me by a skilful workman in London. With 1200 grains in each scale, it turns with $\frac{1}{70}$ of a grain. This is the $\frac{1}{84000}$ of the whole; and therefore about this weight may be known to five places of figures. The proportional delicacy is less in greater weights. The beam will bear near a pound troy, and when the scales are empty it is affected by the $\frac{1}{1000}$ of a grain. On the whole, it may be usefully applied to determine all weights between 100 grains and 4000 grains to four places of figures.

—of Mr. Alchorne:

A balance belonging to Mr. Alchorne, of the Mint, in London, is mentioned, vol. lxxvii. p. 205, of the Philosophical Transactions. It is true to 3 grains with 15 lb. an end. If these were avoirdupois pounds, the weight is known to $\frac{1}{35000}$ part, or to four places of figures, or barely five.

—of Dr. Geo. Fordyce.

A balance (made by Ramsden, and turning on points instead of edges) in the possession of Dr. George Fordyce,

dyce, is mentioned in the lxxvth volume of the Philofophical Tranfactions. With a load of four or five ounces, a difference of one divifion in the index was made by the $\frac{1}{1000}$ of a grain. This is $\frac{1}{384000}$ part of the weight; and, confequently, this beam will afcertain fuch weights to five places of figures, befides an eftimated figure.

THE BALANCE.

The balance of Mr. Magellan:

I have feen a ftrong balance in the poffeffion of my friend Mr. Magellan, of the kind mentioned in § 15, which would bear feveral pounds, and fhewed $\frac{1}{10}$ grain, with one pound an end. This is the $\frac{1}{70000}$ of the weight, and anfwers to five figures. But I think it would have done more by a more patient trial than I had time to make.

—of the Royal Society.

The Royal Society's balance, which was lately made by Ramfden, turns on fteel edges upon planes of polifhed cryftal. I was affured that it afcertained a weight to the feven millionth part. I was not prefent at this trial, which muft have required great care and patience, as the point of fufpenfion could not have moved over much more than $\frac{2}{100}$ of an inch in the firft half minute: but, from fome trials which I faw, I think it probable that it may be ufed in general practice to determine weights to five places and better.

Inferences.

From this account of balances the young ftudent may form a proper eftimate of the value of thofe tables of fpecific gravities, which are carried to five, fix, and even feven places of figures, and likewife of the theoretical deductions in chemiftry that depend on a fuppofed accuracy in weighing, which practice does not authorife. In general, where weights are given to five places of figures, the laft figure is an eftimate

 or

THE BALANCE.

or gueſs figure; and where they are carried farther, it may be taken for granted that the author deceives either intentionally, or from want of ſkill in reducing his weights to fractional expreſſions, or otherwiſe.

Compariſon of weights:

Among the numerous public exertions which our learned neighbours, the French, have made in favour of the ſciences, the determination of the relative proportions of the weights uſed in various parts of Europe, is by no means one of the leaſt. The moſt exact ſtandard weights were procured by means of the ambaſſadors of France, reſident in the various places; and

—by Monſ. Tillet.

theſe were compared by Monſ. Tillet with the ſtandard mark in the pile called the *poids de Charlemagne*, preſerved in the Cour de Monnoies at Paris. His experiments were made with an exact balance made to weigh one mark, and ſenſible to one quarter of a grain. Now, as the mark contains 18,432 quarter grains, it follows that his balance was a good one, and would exhibit proportions to four places, and a gueſs figure. The reſults are contained in Table II. (Appendix), extracted from Monſ. Tillet's excellent Paper in the Memoirs of the Royal Academy of Sciences for the year 1767. I have added the two laſt columns, which ſhew the number of French and Engliſh grains contained in the compound quantities againſt which they ſtand. The Engliſh grains are computed to one-tenth of a grain, though the accuracy of weighing came no nearer than about two-tenths.

CHAP.

CHAP. VII.

ON THE ATTRACTIONS EXERTED BETWEEN BODIES; PARTICULARLY THOSE WHICH THE CHEMISTS CALL ELECTIVE ATTRACTIONS.

AFFECTIONS OF BODIES.

THUS far we have attended chiefly to the changes produced in bodies by an alteration in their temperature, and to the methods of conducting chemical operations. We now proceed to confider thofe actions which take place between the parts of bodies of different kinds. Thefe form a branch of knowledge of the greateft importance, but of fuch an extended nature as to require the utmoft caution to avoid error in endeavouring to acquire it. The whole fcientific part of chemiftry depends on a right interpretation of facts of this kind. In the inveftigation of thofe general truths which may be confidered as laws of nature, we cannot therefore be too careful in diftinguifhing well-eftablifhed facts from the ingenious though inadequate conclufions which theoretical writers are too ready to form.

Great importance of the knowledge of the actions between the parts of bodies.

That property of matter or body by which we think we can beft determine its quantity, is its inertia, or the refiftance it makes to the communication of motion. We cannot perhaps form any idea why there fhould be more difficulty in moving one body than another, except that it really confifts of a larger portion of matter. The perceptible extenfion of the fame body will vary, if

Inertia of matter.

Extenfion.

ATTRACTIONS.

Gravity may perhaps be modified:

if the dimenſions of its pores be either increaſed or diminiſhed; and there is no inconſiſtency in ſuppoſing it at leaſt poſſible that its weight, or the force by which it is urged towards the earth, may not in all caſes continue unaltered, but be capable of modification like the attractions of magnetiſm and electricity. Neither the extenſion nor the weight of bodies appears therefore to be original meaſures of their quantities of matter; how far they may be uſed as ſuch, muſt depend on their coincidence with the inertia.

—but is not found to vary in experiments.

After a proper allowance has been made for the effects of the earth's rotation on its axis, it is found that the power of gravitation, in giving motion to the balls of pendulums, is accurately in proportion to their maſſes, as meaſured by their reſiſtance or inertia. The weights of bodies therefore are meaſures of their quantities of matter; and though the forces with which various bodies of equal magnitude are urged towards the earth, are different, we do not ſuppoſe the attraction or affinity between thoſe bodies and the earth to be ſtronger or weaker in the ſeveral inſtances, but only that the maſſes are greater or leſs.

Uſual inference.

Thus, though a cubic inch of gold weighs more than twice as much as a cubic inch of copper, we do not ſuppoſe a ſtronger attraction between gold and the earth; but conclude that one general force acts on both, whoſe effects are greater on the former body than the latter, becauſe the maſs of the former is really greater than that of the latter.

Effects of attraction:

—coheſive.

The effects of attraction between one body and another are ſo numerous, that we cannot avoid perceiving them every moment. Two ſmooth poliſhed pieces of metal

metal adhere when preffed together. Water and other fluids take the form of globules, and will ftick to various bodies, and pafs into the pores of fponge, bread, or the cavities of fmall tubes. Solid bodies retain their form by the adhefion of their parts; and without this power it is impoffible to conceive how the univerfe could, for a moment, fubfift in its prefent form.

ATTRACTIONS.

Cohefive attraction differs from gravity.

It may be queftioned whether this cohefive attraction be the fame power as gravity. To decide the enquiry, it will be neceffary to compare their manner of action. The force of gravity acts in the inverfe proportion of the fquare of the diftance between the bodies: but the effects of cohefion are found to increafe at a much fafter rate, as the bodies approach; fo that its power is incomparably greateft at fmall diftances. This feems to be a fufficient reafon for confidering gravitation and cohefion as two diftinct powers.

Elective attraction.

The elective attraction of the chemifts—fuch, for example, as when copper, being diffolved in an acid, is feparated, and falls to the bottom in a powdery form, on the addition of iron—may, in all its numerous varieties, be either one general power, acting like gravity, according to the maffes or denfities of the particles; or it may, like magnetifm, be dependent more on the peculiar qualities of thofe particles than on their maffes. If the former were the cafe, we might fimplify our deductions by admitting that cohefion and elective attraction are the fame thing. It will be eafy to examine whether this pofition will, in any one inftance, lead us into an error; and, if it does, it muft be abandoned. Spirit of wine diffolves refin; water does not: hence it will follow, if the attraction depend on the denfity of particles,

Queftion.

CHEMICAL ATTRACTIONS.

Elective attraction does not epend on density.

ticles, that the particles of ſpirit of wine are denſer than thoſe of water. But, again, water diſſolves gums; ſpirit does not: whence, by the ſame reaſoning, we ſhould deduce, that the particles of water are denſeſt. But the true inference is, that if theſe different effects depend on any general law, it does not follow the denſity of the particles; and till that general law is diſcovered, we ought to conſider the various attractions which occur in chemiſtry, as peculiar to the bodies in which they are obſerved.

—probably on figure.

Bergman, Morveau, and other eminent chemiſts, are inclined to the opinion that there is but one general power of attraction in nature, which is modified chiefly by the figure of particles when extremely near each other. But this has not been ſtrictly examined.

Aggregation.

Mixture.

The adheſion of parts of the ſame kind, is called aggregation. Thus, a number of pieces of brimſtone united by fuſion, form an aggregate. The union of bodies of different kinds, in a groſs way, is called mixture. Thus ſand and ſalt of tartar may be mixed together. But when the very minute parts of one body unite with thoſe of another ſo intimately as to form a body which has properties different from thoſe of either of them, the union is called combination, or compoſition. For example, ſand and ſalt of tartar, expoſed to a ſtrong heat, combine, and form a compound called glaſs. The minuteſt parts into which an aggregate can be imagined to be divided without decompoſition, are called integrant parts; but the parts into which it is divided by decompoſition, are called component parts or principles.

Combination, or compoſition.

Integrant and component parts.

Principles

CHEMICAL ATTRACTIONS.

Elements, or firft principles.

Principles which cannot be fubdivided by art, are called elements, or firft principles; and the principles made up of thefe, are called fecondary principles. Some writers carry this order ftill farther; but it muft be confeffed that no means have yet been devifed to fhew unequivocally whether any fuch fubordination of principles exifts. We may indeed difcover the component parts of bodies; but we know nothing of their arrangement.

Heat. See pag. 2, 3.

As the chemical attractions, like other powers of the fame kind, are weaker, the greater the diftance between the parts which act on each other; and as heat enlarges the dimenfions of the bodies; doubtlefs, by feparating their parts, it will not be difficult to explain the effect of heat upon the changes produced in bodies by their elective attractions.

Simple combination.

If two folid bodies, difpofed to combine together, be brought into contact with each other, the particles that touch will combine, and form a compound; and the procefs will go no further, if the compound ftill retain the folid form. But if the compound be of fuch a nature as to have its point of congelation or folidity much lower than the temperature in which the experiment is made, or if it attract water from the atmofphere, it will be fluid; and the effential property of a fluid being, that all its particles may freely move amongft each other, the parts of each body will be at liberty to move in fucceffion, fo as beft to obey the elective attraction. The confequence will be, that a new compound, in a fluid form, will be produced by the union of the two bodies. An inftance of this has already been fhewn in the mixture of ice and falt. Page 19.

Sufpenfion.

If one of the two bodies be fluid at the temperature of

CHEMICAL ATTRACTIONS.

Solvent, or menstruum.

of the experiment, its parts will succeſſively unite with the parts of the ſolid, which will by that means be ſuſpended in the fluid, and diſappear. Such a fluid is called a ſolvent, or menſtruum, and the ſolid body is ſaid to be diſſolved. Thus water diſſolves ſalt, mercury diſſolves gold, glaſs of lead diſſolves ſand, &c.

Water.

In the humid way, where the fluid ſtate is produced by means of water, and in many caſes of which the diſſolved bodies may be recovered by evaporating the water, it is uſual to attend only to the actions of the ſuſpended bodies, and neglect the fluid, becauſe common to all experiments of this kind. But as the water certainly has as great a ſhare in modifying the effect which follows, as any other of the bodies preſent, the elective attractions between bodies held in ſolution in water, will not in general be the ſame as when the menſtruum is ſpirit, oil, or æther; or when, in the dry way, one of the bodies is rendered fluid by ſtrong heat.

Cauſe of error in eſtimating the attractions.

Limits of ſaturation:

Some ſubſtances unite in all proportions. Such, for example, are acids in general, and ſome other ſalts, with water; and many of the metals with each other. But there are likewiſe many ſubſtances which cannot be diſſolved in a fluid, at a ſettled temperature, in any quantity beyond a certain proportion. Thus water will diſſolve only about one fourth of its weight of common ſalt; and if more be added, it will remain ſolid. A fluid which holds in ſolution as much of any ſubſtance as it can diſſolve, is ſaid to be ſaturated with it. But ſaturation with one ſubſtance does not deprive the fluid of its power of acting on and diſſolving ſome other bodies, but in many caſes increaſes that

in fluids:

that power. For example, water, faturated with falt, will diffolve fugar; and water, faturated with fixed air, will diffolve iron, though, without that addition, its action on that metal is fcarcely perceptible. The word faturation is likewife ufed in another fenfe by chemifts: the union of two principles produces a body whofe properties are different from thofe of its component parts, but which refemble thofe of the predominating principle. When the principles are in fuch proportion as that neither may predominate, they are faid to be faturated with each other; but if otherwife, the moft predominant principle is faid to be under-faturated, and the other over-faturated.

CHEMICAL ATTRACTIONS. —in general.

Fluids in general diffolve a greater quantity of any fubftance the higher the temperature. This probably arifes from the fluidity of the body in folution being promoted by the heat.

Solution affifted by heat.

When two bodies, which would not otherwife combine, are made to unite by the addition of a third, the latter is called a medium. Thus the iron and water, in the inftance lately mentioned, are faid to have combined by the medium of fixed air.

Medium of combination.

It often happens, on the contrary, that the tendency to combination between a folvent and another body, is weakened or deftroyed by the addition of a third. Thus fpirit of wine weakens the action of water upon moft falts, and of courfe feparates them from it. If to a faturated folution of nitre in water there be added an equal meafure of ftrong ardent fpirit, the nitre becomes folid, and falls down in an inftant to the bottom of the phial. The fubftance thrown down from a folvent by the addition of any other matter, is faid to

Separation, or precipitation.

be

CHEMICAL ATTRACTIONS.

be precipitated, and many ſuch products are called precipitates.

Simple elective attraction.

When a compound of two principles is ſo affected by the addition of a third, that a new compound is formed of this laſt principle and one of the other two; at the ſame time that the principle which was part of the original compound, but does not enter into the ſecond combination, is diſengaged; the decompoſition and new combination are ſaid to be produced by ſimple elective attraction or affinity.

Examples of ſimple elective attraction:

Moſt operations of nature or art are ſo complex, that it is exceedingly difficult to exemplify theſe effects. The following inſtance will exhibit an effect of ſimple elective attraction, if we overlook the effect of the water, which is preſent in both ſalts. Common ſalt conſiſts of two principles. The one is the mineral alkali commonly known by the name of ſalt of ſoda; and the other is the marine acid, which, when combined with water, is known by the name of ſpirit of ſalt. If the vitriolic acid be poured upon common ſalt, it will attract the alkali more ſtrongly than it is attracted by the marine acid. The conſequence will be, that it will unite with the alkali, and form a new compound, called Glauber's ſalt, while the marine acid flies off in the form of air. This air, meeting with moiſture in the atmoſphere, combines with it, and forms the common marine acid viſible in the form of white fumes.

—in the humid way:

—in the dry way.

In the dry way: If a combination of lead and ſulphur be fuſed with iron, the ſulphur unites with this laſt, and leaves the lead free.

If we were to ſpeculate on theſe events, it would be be eaſy to ſhew from what ſuppoſed action among the particles they may happen. If a particle of alkali be ſurrounded by particles of marine acid, and the vitriolic acid be added, the particles of theſe laſt may be ſo ſtrongly attracted by the alkali as to approach it, and remove the particles of marine acid beyond the limit of ſenſible attraction. This effect may be facilitated by the action of heat, which increaſes the diſtances between parts of bodies; and the diſengaged ſubſtance may aſſume either the ſolid, fluid, vaporous, or aerial ſtate, according to the temperature and the peculiar properties of the body itſelf in that reſpect.

Double elective attraction.

Where two bodies, each conſiſting of two principles, are ſo diſpoſed as to act on each other, and the order of the principles changes in ſuch a manner as to form two other bodies compoſed of different principles, the change is ſaid to be produced by double affinity, or double elective attraction.

Example: in the humid way:

In the humid way: Let mercury be diſſolved in the nitrous acid (or ſpirit of nitre of the ſhops) until the acid will take up no more. The ſolution will then conſiſt of a mercurial ſalt diſſolved in water. Let tartar, which is a ſalt conſiſting of a peculiar acid united with the vegetable alkali, be added. The conſequence will be, that the alkali of the tartar will quit its own acid, and, uniting with the nitrous acid, will form nitre, which will continue diſſolved; and, on the other hand, the acid of the tartar, being diſengaged, will unite itſelf to the mercury, and form a ſalt, which, on account of its inſolubility, will fall down in the form of a powder.

—dry way.

In the dry way: If an alloy of gold and copper be

CHEMICAL ATTRACTIONS.

fuſed with the antimony of the ſhops, which conſiſts of ſulphur and a metallic body called regulus of antimony, the ſuphur will unite with the copper, and float above, while the gold and the regulus combine together, and occupy the lower part of the crucible.

Numerical expreſſion of affinity.

One of the principal objects of chemical reſearch conſiſts in the numerical expreſſion of the attractive powers of bodies. If this were well aſcertained, it is probable we ſhould be able to foretel, not only the effects of ſimple or double affinity, but likewiſe in what caſes the compounds of three or more ſubſtances take place. See Appendix.

Mechanical properties of bodies do not follow the properties of their component parts.

No regular connection has been yet diſcovered between the ſolubility in water, the fuſibility, volatility, ſpecific gravity, and other obvious properties of the component parts of bodies, and of the compounds they produce. Hence it happens, in humid operations, that the inſoluble products will either fall to the bottom, or riſe to the ſurface, according to their weights. In ſome proceſſes, all the products will be thus ſeparated; and in others the whole will remain diſſolved. In the dry way likewiſe ſome products will riſe, others will become fluid, and others fixed, ſo as to require a ſtronger heat to fuſe them than before.

Utility of theſe changes.

Theſe ſeveral changes afford means to the chemiſt of ſeparating bodies from each other. When two different kinds of ſalt are diſſolved in water, it would be almoſt impoſſible to ſeparate them if they were both equally ſoluble; becauſe evaporation would leave both in a confuſed maſs. But where the one is more ſoluble than the other, the latter will begin to be ſeparated, and may be taken out at a period of the evaporation, at which

which the whole of the former will remain fufpended. So likewife the advantages derived from the proceffes of diftillation, fublimation, and other dry operations, are founded on thefe different properties of bodies.

Cryftallization.

The parts of all bodies which take the folid ftate are difpofed to arrange themfelves in fuch a manner as to produce fome regular geometrical figure in the folid. Thus ice, during its formation in water, or even in the open air, always affumes a regular figure, as far as circumftances will permit. The fame is obfervable in the fixation of other fluids, and alfo in the feparation of bodies from their folvents, as falts from water. This property is called cryftallization, and the regularly-figured bodies are called cryftals. The figure of cryftals is influenced by fo many circumftances—fuch as the quicknefs of their formation, the temperature and agitation of the fluid, the prefence of light, and others—that little dependence can be placed on it as an indication of the compofition of bodies; though the experienced operator will doubtlefs derive fome advantage by attending to it.

Polarity of the particles of bodies.

The regular arrangement of parts in cryftallization is fuppofed by fome to be the confequence of a property in the particles of bodies, fimilar to polarity in magnetifm. And indeed it feems reafonable to infer, that two compounded particles, coming together by attraction, undifturbed by any other caufe, fhould difpofe themfelves fo as to apply fuch fides of each together, as are occupied by principles the moft attractive of each other.

BOOK II.

PARTICULAR CHEMISTRY.

SECTION I.

OF THE GENERAL PRINCIPLES OF BODIES.

CHAP. I.

CONCERNING THE GENERAL DIVISION OF CHEMICAL PRINCIPLES.

PRINCIPLES OF BODIES. Arrangement.

AMONG the various divifions or arrangements of chemical principles, that which follows their refpective degrees of fimplicity muft undoubtedly prove the moft ufeful, becaufe the more compounded bodies will eafily affume a regular order when their refpective principles are known and properly claffed. There is however a limit in the advantages that may be derived even from this method of divifion. The more we fucceed in fimplifying the principles of bodies, the more difficult it is to determine truly what paffes in

PRINCIPLES OF BODIES. Arrangement.

chemical operations; becaufe thefe principles, when in their moft diftinct ftate, have the aerial form, and cannot therefore be managed or weighed without confiderable difficulty. From this caufe it is that, while we have no difputes concerning the changes of combination in groffer and lefs fimple fubftances, the moft eminent chemifts often differ in their opinions concerning the tranfitions of firft principles from one combination to another; and are not agreed concerning the exiftence of fome of them. The peculiar properties of bodies may be changed, either by the addition or fubtraction of fome of their component parts; and it is eafy to form a notion that fuch a change may alfo happen by a mere alteration in the difpofition or relative arrangements of their parts, without any change in their quantities. To determine which of thefe events takes place, when we behold only the confequent change, is fometimes impracticable, for want of a fufficient number of facts; and in moft cafes the complete inveftigation requires the unprejudiced and patient exertion of all the powers of the mind. It will be proper therefore, in an elementary arrangement, to fix our attention chiefly on the moft palpable component parts of bodies, which are fufficiently fimple; and where they are not the fimpleft, to fpeak of their principles in the analytical method.

Enumeration.

The component parts of bodies are either,

1. Principles whofe exiftence is doubtful: thefe are heat, light, and phlogifton.

2. Principles which have not been exhibited in a folid or fluid ftate, or diffolved in water, in any notable proportion;

proportion: thefe are vital air, phlogifticated air, and inflammable air.

PRINCIPLES OF BODIES. Enumeration.

3. Water.

4. Earths.

5. Alkalis.

6. Acids.

7. Metals.

8. Mineral combuftibles.

9. Parts of organized fubftances, whether obtained by mechanical preffure, by fimple folution in water or ardent fpirit, by a gentle or a ftrong heat, by the action of folvents, or by fpontaneous decompofition.

Animal, vegetable, and mineral kingdoms.

The only general divifion of bodies at prefent referred to in the writings of modern chemifts, is that by which they are claffed into three kingdoms, called the animal, vegetable, and mineral kingdoms. The kind of bodies arranged in the two firft kingdoms is obvious from the terms; and all other bodies are confidered as belonging to the mineral kingdom.

Salt.

Alkalis, acids, and fuch compounds as they enter into, are diftinguifhed generally by the name of falts. The leading character of falts is a ftrong tendency to combination, there being no bodies in nature which are not acted upon by fome faline fubftance. This tendency appears in their eminent degree of folubility in water. All bodies known only by the name of falts are foluble in lefs than two hundred times their weight of boiling water. The fame caufe produces their fapidity, or tafte, which was regarded by the earlier chemifts as a diftinctive character of falts.

Metals are fometimes claffed with combuftible bodies; and, ftrictly speaking, they are combuftible. But

PRINCIPLES OF BODIES. Metals.

as none of them poffefs this property in fuch a degree as to burn away in the common air, without the co-operation of other inflammable bodies, which are neceffary to maintain their high temperature; and as they poffefs other remarkable properties peculiar to themfelves—they require to be placed in a feparate clafs.

CHAP.

CHAP. II.

CONCERNING HEAT, LIGHT, AND PHLOGISTON, CONSIDERED AS COMPONENT PARTS OF BODIES.

IT has already been ftated, that the exiftence of heat, as a peculiar fubftance, is not proved; and, among philofophers of the firft eminence, there are feveral who think the opinion that it is a mere modification, is the moft probable. With regard to light, the opinions of the world are lefs divided. It is generally taken for granted that light is a fubftance, or an emanation of particles of prodigious minutenefs, which are projected in right lines, with extreme velocity, from luminous bodies; and that they are repelled from all bodies at certain diftances, and at lefs diftances attracted, fo as to produce all the effects of reflection, refraction, and inflection, in the rays they compofe. Thefe particles are fuppofed to be either of various magnitudes, or differently acted on by other bodies, and from that caufe to be feparable from each other; in which feparate ftate they affect the organ of fight with the fenfation of various colours.

DOUBTFUL PRINCIPLES. Heat. Page 6. 21. Light. Newton's Optics, fub fine.

Many philofophical writers have confidered it as an axiom, that a body cannot act where it is not*; and have

Subtle fluid.

* It may be obferved that this pofition is very doubtful. All our knowledge is derived from an obfervation of the actions which take place between bodies. Now we never fee bodies act where they are,

DOUBTFUL PRINCIPLES.

have thence inferred, that the univerfe is occupied by a fubtle fluid, whofe action caufes bodies to approach and recede from each other in the phenomena of attraction and repulfion.

Light.

Light is confidered by fome authors * as a modification of this fluid, in the fame manner as found is admitted to confift in an undulatory motion of the air, communicated from fonorous bodies. We fhall not here examine the merits of this queftion, but fhall only obferve, that no decifive experiments have yet been offered in fupport of either opinion.

Burning lens, or mirror.

When a great number of rays of light are made, either by a burning glafs or concave fpeculum, to pafs through a fmall fpace, they excite a moft powerful heat in bodies placed in the focus. The ftrongeft heat yet known is of this kind. The heat produced in bodies by the action of light, is in general greater, the more light is caufed to difappear. Bodies which either tranfmit or reflect the light in large quantities, are very little heated by the focus of a burning apparatus. Similar coatings of black paint, the one upon a plate of iron, and the other upon a plate of pafteboard, being expofed in circumftances perfectly fimilar to the fun's rays, the heat produced was greater in the iron, though the mafs

are, but always where they are not. In attraction and repulfion this is evident; and in impulfe, there are the beft reafons to conclude that the impelling body approaches within a certain diftance of the impelled body, and then acts by its repulfive force without contact. Even the particles of bodies do not touch; for, if they did, how could a diminution of temperature bring them nearer together? Of the penetrability of matter we need not fpeak in this place.

* Of thefe the great Euler ftands firft. See his Letters to a German Princefs.

DOUBTFUL PRINCIPLES.

of this laſt was near ten times that of the paſteboard *. It has been often aſſerted, that heat and light are the ſame thing. But the light of a fire will paſs through a pane of glaſs, and the heat will remain behind, as is moſt evidently ſhewn by interpoſing the glaſs between the fire and a concave metallic mirror†. The focus of the mirror, though as luminous as before, will produce no heat. A bright table-ſpoon may be uſed where a mirror is not at hand. The preſence of light has a conſiderable effect upon the proceſs of cryſtallization; and in many inſtances it produces a change in bodies of an oppoſite nature to that which they ſuffer from combuſtion.

Light and heat differ.

During the combuſtion of inflammable bodies, we perceive a continual eſcape of volatile matter; and as the fixed reſidue is uſually found to be much leſs than the original weight of the body which has been burned, it was natural for the earlier chemiſts, who were unacquainted with the nature and quantity of the volatile products, to infer that combuſtion conſiſted in the eſcape of ſome principle which inflammable bodies poſſeſſed, but which was wanting in ſuch as could not be burned. This doctrine has been occaſionally modified till our time; and the experiments made by expoſing to heat a metal that had been burned, together with another more inflammable body, in a cloſed veſſel, in which the latter was conſumed, while the former recovered its inflammability, were, till lately, received as undoubted proofs that the principle of inflammability or phlogiſton

Phlogiſton.

* Dr. George Fordyce, in Phil. Tranſ. Vol. lxxvii. p. 31?.

† Scheele on Air and Fire, p. 70. Engliſh tranſlation.—Mariotte in Mem. Acad. Par. 1682.

had

DOUBTFUL PRINCIPLES.

Phlogiston.

had paſſed from the one body to the other. It was indeed urged as an objection, that metallic bodies, ſo far from loſing weight by calcination, do really become heavier: and later experiments ſhewed that this increaſe of weight was gained from the air; the abſolute neceſſity of whoſe preſence in combuſtion had been formerly either overlooked, or ſlightly regarded. But this was explained from the doctrine of affinity, by the ſuppoſition that the pure air of the atmoſphere, combining with the baſe of the combuſtible body, ſet its phlogiſton, or fire, at liberty. The modern doctrine of heat however appears to ſhew, that the increaſe of temperature arifes from the air, and not from the combuſtible body; and this conſideration has led ſeveral eminent French chemiſts to reject phlogiſton altogether*, and to conſider the proceſs of combuſtion as nothing elſe but the act of combination of vital air with the combuſtible body; the matter of heat, which according to them is combined with the air, being ſet at liberty.

Page 33.

Among the chemiſts who maintained the old opinion it became therefore an object of enquiry, whether the air abſorbed in combuſtion really either expels, or combines with, any principle common to all inflammable bodies. For if this ſhould be reſolved in the affirmative, the ſubſtance found would be the

* This doctrine may be ſeen diſplayed at length in the notes annexed to Kirwan's Eſſay on Phlogiſton, ſecond edition. M. Lavoiſier is the firſt of the chemiſts who explained and illuſtrated the new doctrine by a ſet of accurate experiments, and a judicious arrangement of the known facts; but M. Bayen may be conſidered as the firſt modern who, upon rational grounds, rejected the phlogiſton. The excellent John Mayow is the father of this doctrine.

prin-

principle of inflammability or phlogifton. The evident way to determine this muft be, to heat combuftible bodies in clofed veffels. The moft predominant volatile product is, in thefe cafes, found to be a very light, aerial matter, which is very inflammable when common air is prefent; and is known by the name of inflammable air. Mr. Kirwan firft announced this as the phlogifton.

DOUBTFUL PRINCIPLES. Phlogifton.

The great queftion now is, whether inflammable air be contained in all combuftible bodies, fince they do not all emit it by mere heat; and it is evident that, if combuftion can be effected without it in any one inftance, it cannot be the indifpenfable and univerfal principle of inflammability. Its exiftence is denied in fulphur, phofphorus, charcoal, metals, and fome other fubftances. It may however be obtained by heating thefe, if water be prefent: whether it is afforded by the fubftance under examination, or by the water, is therefore the fubject of controverfy.

Queftion.

We may refume this fubject as we advance; but enough has been faid in this chapter to fhew the learner that the exiftence of heat, light, and phlogifton, as chemical principles of bodies, is not yet incontrovertibly eftablifhed.

CHAP.

CHAP. III.

OF PHLOGISTICATED, DEPHLOGISTICATED OR VITAL, AND INFLAMMABLE AIR, AND OF THE COMPOSITION AND GENERAL PROPERTIES OF WATER.

COMBUSTION.

Page 50.

WHENEVER combuſtion, or an equivalent proceſs, is carried on in a veſſel containing atmoſpherical air, which is incloſed either by inverting the veſſel over mercury, or by ſtopping its aperture in a proper manner, it is found that the proceſs ceaſes after a certain time; and that the remaining air, which is about three-fourths of the whole bulk, is of ſuch a nature, as to be incapable of maintaining combuſtion, or ſupporting the life of animals.

Effects of combuſtion on common air.

From this experiment it is clear that one of the following deductions muſt be true: 1. The combuſtible body has emitted ſome principle which, by combining with the air, has rendered it unfit for the purpoſe of combuſtion: Or, 2. It has abſorbed part of the air, which was fit for that purpoſe, and has left a reſidue which is of a different nature: Or, 3. Both events have happened; namely, that the pure part of the air has been abſorbed, and a principle has been emitted which has changed the original properties of the remainder.

Obſervations.

The facts muſt clear up theſe theories. The firſt cannot be altogether true, becauſe the reſidual air is not only of leſs bulk, but of leſs ſpecific gravity, and the burned body is heavier than before. The air cannot

cannot therefore have received fo much as it has loft. The fecond is the doctrine of the philofophers who deny the exiftence of phlogifton, or a principle of inflammability. And the third muft be adopted by thofe who maintain that fuch a principle efcapes from bodies during combuftion. This refidue was called phlogifticated air, in confequence of fuch an opinion.

COMBUSTION. Opinions.

Phlogifton.

In the opinion that inflammable air is the phlogifton, it is not neceffary to reject the fecond deduction. For the pure or vital part of the air may unite with inflammable air, fuppofed to be in a fixed ftate in the combuftible body; and if the product of this union remain fixed, it is plain that the refidue of the air after combuftion will be the fame as it would have been if the vital part had been abforbed by any other fixed body. Or if the vital air be abforbed while the inflammable air is difengaged, and unites with the aerial refidue, this refidue will not be heavier than before, unlefs the inflammable air it has gained exceeds in weight the vital air it has loft.

Compofition of the atmofphere.

It is rendered more probable that the air of the atmofphere confifts of a mixture of a vital and a noxious part, by the fact, that, when fixed bodies have been burned or calcined (for example, mercury converted into precipitate per fe), the vital air may be again extricated from fome of them. This is found to maintain combuftion in the moft effectual manner, and is almoft totally abforbed in that procefs, inftead of leaving a refidue fuppofed to be changed by phlogiftication. And, on the other hand, there is no unequivocal proof that vital air can be obtained from the phlogifticated part by any operation whatever.

Vital

VITAL AIR.

Subſtances which afford vital air.

Vital air may be obtained by heat from nitre, from alum, from mercury calcined without addition, and uſually called precipitate per ſe; from red precipitate, from minium, from manganeſe, and from lapis calaminaris. Moſt nitrous and vitriolic ſalts afford it by heat. It is contained in the bladders of ſea-weed, and in waters. The green vegetable matter formed in water emits it when expoſed to the ſun's light; and it is found in general that the leaves of plants, in like circumſtances, emit vital air. Whence it appears that there are abundant proviſions for reſtoring the purity of the air, which is continually injured by combuſtion, reſpiration, fermentation, and other proceſſes.

Reſpiration is a proceſs of the ſame kind as combuſtion.

The reſpiration of animals produces the ſame effect on air as combuſtion does; and their conſtant heat appears to be an effect of the ſame nature. When an animal is included in a limited quantity of atmoſpherical air, it dies as ſoon as the air is vitiated. Vital air, in like circumſtances, maintains the life of animals much longer than common air.

Vegetables affect the air.

Vegetables do not thrive in vital air. Theſe appear to render common air purer, by abſorbing its phlogiſticated or noxious part. They emit vital air when the ſun ſhines on them. This is ſuppoſed to ariſe from the decompoſition of water.

Nitrous air uſed as a teſt.

Several of the metals, and other combuſtible ſubſtances, when diſſolved in ſpirit of nitre, afford or extricate, by an efferveſcence, a kind of air called nitrous air, of which we ſhall more particularly ſpeak in its place. Mercury is one of theſe metals. If this air be mixed with any other air in which vital air is contained, it unites with this laſt, and forms red fumes,

5 which

which fall down, and are found to confift of nitrous acid. The air itfelf is diminifhed in bulk by the lofs; and hence the nitrous air becomes a teft of the goodnefs of refpirable air. For the diminution is greater the greater the quantity of vital air.

INFLAMMABLE AIR.

All animal or vegetable fubftances which can be burned in the open air, charcoal excepted, will afford inflammable air, if heated in clofed veffels. This is ufually mixed with air of other kinds, and with oleaginous matter. Charcoal and feveral metals afford inflammable air by heat, if water be prefent. Some metallic fubftances, during their folution in acids, afford or extricate inflammable air, which is of the pureft kind. This fluid is very light, according to its purity. It is ufually about ten times as light as an equal bulk of common air; but it is faid to have been obtained feventeen times lighter *. The common procefs for obtaining it is, to diffolve iron filings or fhavings in diluted vitriolic acid.

Subftances which afford inflammable air.

If a mixture of about two parts, by meafure, of inflammable air, with one of vital air, be fet on fire, in a ftrong clofed veffel, which may be done by the electric fpark, the airs, if pure, will almoft totally difappear, and the product will be water and an acid. Till lately, the produce was thought to be mere water; and feveral eminent chemifts at Paris have ftrongly infifted that it was equal in weight to the two airs made ufe of. This agreement however has never been proved †; and, as every kind of air ufually

Water produced by combuftion of vital and inflammable air.

* By Morveau. See the Aeroftat de Dijon.

† When we confider the great bulk and fmall weight of air, the magnitude of the apparatus, and the imperfection of the beft balances,

WATER.

Whether water be a compound.

ufually holds a large proportion of water in folution, from which the aqueous product might be derived, it ftill remains a problem to be decided, whether water, with refpect to the prefent ftate of our knowledge, be a fimple or a compound fubftance. For the water may either be formed by the union of the two airs, or the real airs may be totally employed in forming the acid, while the water is fimply condenfed upon their lofing the aerial form.

The extenfive utility of water;

Water is a fubftance which enters into fo many operations of nature and art, that a full defcription of its properties would include moft of the properties of other bodies. Its weight is ufed as the meafure of fpecific gravity; its capacity for heat is affumed as the ftandard of comparifon for other bodies; its temperature at the changes from folidity to fluidity and to the elaftic ftate, is taken as the fixed points for thermometers; and, in a word, the folubility of bodies denotes, in general, the action which this fubftance exerts upon them.

—its general properties.

Water being ufually met with in thefe climates in the fluid ftate, its properties are in moft cafes treated of under that form. If it be heated it gradually expands, and is converted into vapour at 212° of Fahrenheit, with fuch rapidity as to counteract the effect of heat in raifing its temperature. In a ftrong clofed metallic veffel it may be heated nearly red hot, and in

Page 18.

balances, none of which in practice weigh beyond five places of figures (p. 67—69), we fhall find fufficient reafons to queftion the accuracy of conclufions, which fuppofe the quantities of air and water to be rigoroufly afcertained. Thefe reafons are ftill more enforced by the confideration, that the experiments of Dr. Prieftley and M. Lavoifier do not agree.

this

WATER.

this ſtate its ſolvent powers are greatly increaſed. If the veſſel be opened, ſteam ſuddenly ruſhes out, and the temperature of the fluid falls inſtantly to 212°. When water is cooled, it gradually contracts till within 8° of freezing, and then expands till it freezes. The parts of the water which firſt become ſolid by freezing, have the form of ſword-blades, croſſing each other at angles of 60 degrees. It will ſhoot out into this form in the open air, as may be ſeen in ſnow or hoar froſt upon trees. Ice is conſiderably lighter than water, and therefore floats upon it. The expanſion of ice at the time of its formation is made with ſuch force as to burſt the ſtrongeſt metallic veſſels: and the expanſion of ſteam is prodigiouſly great. This laſt power, being very manageable, by transferring greater or leſs quantities of ſteam into the veſſels of apparatus, or by condenſing it, has been applied to the moſt important mechanical uſes in the ſteam engine, and will doubtleſs be applied to many more.

General properties of water.

Ice.

When water is included in a metallic globe or veſſel, called the eolipile, which has only a very ſmall aperture, and it is then made to boil, the ſteam iſſues out very violently, and will ſtrongly urge a fire in the ſame manner as bellows. This has been thought to prove a decompoſition of the water. But it is not the ſteam which excites the fire, but the air it drives before it. For an eolipile will not produce this, but the contrary effect, unleſs a body of air be interpoſed between its aperture and the fire *.

Effects of the eolipile.

The denſity of water † is ſuch that a cubic foot

Denſity of water

* Lewis's Philoſophical Commerce of Arts, p. 21.

† This was found by Cotes, who ſays it is very nearly ſo. See his Hydroſtatical Lectures, p. 76, ſecond edition.

WATER. weighs 1000 ounces avoirdupois weight. This fortunate concurrence of unity of meaſure with a round number in the weight, renders the common tables of ſpecific gravities very uſeful in computations. For the numbers will denote the avoirdupois ounces in a cubic foot of each ſubſtance, provided the ſpecific gravity of water be taken to be 1000.

Specific gravity of water.

What waters are pureſt.

The pureſt common waters are the lighteſt, and lather well with ſoap. For chemical purpoſes, water ſhould be boiled on a common fire for a ſhort time, to diſſipate any volatile animal or vegetable impregnation it may poſſeſs, and afterwards diſtilled to about one half. The water which comes over is very pure, and the accurate chemiſt ſhould uſe no other. On account of the extenſive uſe and importance of diſtilled water, it is adviſable not to perform this operation but with veſſels kept for that and no other purpoſe.

CHAP.

CHAP. IV.

OF THE SIMPLE OR PRIMITIVE EARTHS.

CHEMISTS diſtinguiſh ſuch ſubſtances by the name of pure earth, as are brittle, incombuſtible, infuſible by the heat of furnaces, not ſoluble in ſeveral hundred times their weight of water, and deſtitute of metallic ſplendour. There are few earthy ſubſtances which may not be reduced by analyſis to one of the five following primitive earths:—the ſiliceous, argillaceous, calcareous, ponderous, and magneſian earths; or otherwiſe, taken ſubſtantively, they are called ſilex, clay, lime, barytes, and magneſia. EARTHS. Five primitive earths.

The adamantine ſpar, the jargon of Ceylon, and a mineral ſubſtance from New South Wales, have afforded earthy ſubſtances which, as far as experiments have yet determined, are different from any of theſe five. But they will not materially affect the general arrangement of chemiſtry, until future reſearches ſhall have proved that they are more abundantly found than at preſent we have reaſon to ſuſpect. New earths.

In ſome ſyſtems a diſtinction is made between earths and ſtones; but this is of no utility in the enquiry reſpecting their component parts and properties. A ſtone is nothing more than a hard earthy maſs, and an earth in powder is an aggregate of very minute ſtones. Stones.

Siliceous earth abounds in all natural bodies which are hard enough to ſtrike fire with ſteel. Of theſe Siliceous earth.

EARTHS. rock cryſtal, quartz, flint, gritſtone, jaſper, and moſt of the precious ſtones or gems, are the chief ſpecimens. Like all other ſimple ſubſtances, it is never found pure in nature. The leading or principal character of this earth is, that it is not perceptibly acted upon by any acid but that of fluor ſpar. Alkalis diſſolve it in the moiſt as well as in the dry way, but moſt efficaciouſly and in all proportions in the latter. Hence the method of obtaining ſiliceous earth in a ſtate of purity conſiſts in diſſolving cryſtal or quartz in a large proportion of fixed alkali in ſtrong fuſion: for example, four parts by weight of the ſalt to one of the earth. This combination will unite with water, in which it muſt be

Liquor of flints. diſſolved. The ſolution is uſually called liquor of flints. An exceſs of acid being added, will combine with the alkali, and ſuch other earths as may have exiſted in the natural ſpecimen; and the pure ſiliceous earth, being inſoluble in water, will fall to the bottom. Repeated waſhing in diſtilled water will ſeparate all the extraneous matter from theſe particles, which, when dried, conſiſt of ſiliceous earth uncombined with any other ſubſtance.

Pure ſiliceous earth. The particles of ſiliceous earth, thus obtained, are in a ſtate of ſuch minute diviſion, that they will remain ſuſpended for a conſiderable time in water; and this fluid, violently heated in a ſtrong cloſed veſſel, will diſſolve a portion of it. Siliceous earth is unalterable in the moſt violent heats chemiſtry can produce in a furnace. Rock cryſtal, which is the pureſt ſpecimen of this earth, of which it contains ninety-three parts in the hundred, has been fuſed by flame urged upon it by a ſtream of dephlogiſticated air from a blow-pipe. With fixed

fixed alkalis, in the proportion of about double its own weight, it forms glafs. Calcined metals, efpecially lead, alfo diffolve it, and form glafs by fufion. The combination of this earth with fluor acid is very fparingly foluble in water.

Argillaceous earth.

The principal natural fpecimens of argillaceous earth are, clays, properly fo called, marles, boles, flates or fchiftus, and mica. In none of thefe, except the flagftone, does the argillaceous earth amount to fo much as half their weight, though their predominating qualities appear to depend upon it. The moft obvious characters of this earth are, an adhefion to the tongue, or any wet and foft body, in the more folid fpecimens; and a remarkable tenacity, ductility, or kneadability ferve to diftinguifh moiftened clays in a moft eminent degree. It is foluble in acids, but alkalis act much lefs upon it, either in the dry or moift way, than they do on filiceous earth. Alum is a combination of argillaceous earth with vitriolic acid. If the concrete volatile alkali be added to a folution of pure alum, the alkali and acid unite, while the clay falls to the bottom, united only with a fmall quantity of fixed air. The fluid muft be abftracted by decantation, and the precipitate wafhed with diftilled water, and dried.

Earth of alum.

Common clays.

Clays may be eafily diffufed and fufpended in water, but are not foluble in any fenfible degree. The fudden application of ftrong heat hardens their external parts, which afterwards burft by the explofion of the moifture within. By a more gradual heat, pure clay contracts very much, becomes hard and full of cracks or fiffures. The prefence of filiceous earth in common

EARTHS.

clays, where it ufually conftitutes above half the weight, renders the contraction more uniform throughout, and prevents the cracks, probably in no other way than by rendering them more numerous, and too fmall to be perceived. When thus baked, it conftitutes all the varieties of bricks, pottery, and porcelain. Thefe, if baked in a ftrong heat, give fire with fteel; a property that may be attributed to the filiceous earth they contain, which cannot act on the fteel unlefs firmly fet in the hardened clay. The dimenfions of pottery are lefs, the greater the heat to which the article has been fubjected. On this property is conftructed a thermometer for meafuring the heat of furnaces, by igniting a fmall brick of known dimenfions therein, and afterwards meafuring its contraction *. Baked clay is no longer kneadable with water, though as finely pulverized as mechanical means can go. Hence it has been inferred that clays owe their ductility to a kind of gluten which is fuppofed to be diffipated by heat. They recover that property however by folution in an acid and precipitation; whence it fhould feem to depend either on a minute portion of acid contained in clays, or the fmallnefs of the particles when precipitated.

Pottery.

Thermometer for ftrong heat.

Calcareous earth:

Calcareous earth, or lime, predominates in moft ftones which are foft enough to be fcratched with a knife. Thefe are chalk, limeftone, marble, fpars, gypfum, or plafter ftone, and various others. As the lime is moft frequently combined with fixed air, it is ufual for mineralifts to drop a fmall quantity of nitrous acid

* See Wedgwood in Phil. Tranf. vol. lxxii. and lxxiv.

upon

upon the ſtones they are deſirous of claſſing; and if it froths by the eſcape of the fixed air, they conclude that lime enters into the compoſition. To obtain pure calcareous earth, powdered chalk muſt be repeatedly boiled in water, which will deprive it of the ſaline impurities it frequently contains. It muſt then be diſſolved in diſtilled vinegar, and precipitated by the addition of concrete volatile alkali. The precipitate, when well waſhed and dried, will conſiſt of lime united to fixed air; the latter of which may be driven off by heat, if neceſſary.

Method of obtaining it pure.

If chalk, marble, limeſtone, ſpar, or any other ſpecimens of this earth, containing fixed air, be expoſed to continued ignition, they give out fixed air and water, to the amount of near half their weight. The remainder, conſiſting chiefly of lime, has a ſtrong tendency to combination, and attracts water very powerfully. The addition of water to lime produces a very conſiderable heat, attended with noiſe, and agitation of the parts, which break aſunder; and a phoſphoric light is ſeen if the experiment be made in the dark. Lime thus ſaturated with water is ſaid to be ſlaked. Water diſſolves about one ſeven hundredth part of its weight of lime, and is then called lime-water. This ſolution has an acrid taſte, and turns ſyrup of violets to a green colour. If lime-water be expoſed to the open air, the lime attracts fixed air, and is by that means converted into chalk; which, not being ſoluble in water, forms a cruſt on the ſurface, formerly called cream of lime, that, when of a certain thickneſs, breaks and falls to the bottom: and in this way the whole of the lime will in time be ſeparated.

Lime, or quick-lime.

Slaked lime.

EARTHS.

Mortar.

The paste of lime and water, called mortar, has a degree of adhesion and ductility, though much less than clay. When dry, it is friable like chalk. A mixture of sand, or broken earthen vessels, greatly increases its firmness, which it seems to effect by rendering it more difficult for the parts to be removed with respect to each other. When mortar is left to dry by the gradual evaporation of its superfluous water, it is very long before it obtains its utmost degree of firmness. But if dry quick-lime be mixed with mortar, it gradually absorbs the superfluous water, and the mass becomes solid in a very short time.

Gypsum, or plaster of Paris.

Gypsum, or plaster of Paris, consists of lime united to the vitriolic acid, together with water. If this substance be exposed to a moderate heat, part of the water is driven off. The dry powder which remains may be mixed with water to the consistence of thin paste, and poured into a mould; and soon afterwards it suddenly becomes solid, at the same time that it is a little heated, and its bulk somewhat increased. This effect may be explained by observing that the particles of the gypsum are at first simply wetted by the water, in the same manner as happens with clay; and for that reason no other effect takes place, than the production of an imperfect degree of fluidity, from the motion of the parts among each other being facilitated: but when the water, by the gradual progress of the action between it and the dried gypsum, becomes combined in the same manner as before the calcination, it is absorbed, and enters into the composition of a solid body; the imperfect fluidity, arising from the presence of uncombined water, disappears, heat is developed, and the

 whole

whole mafs takes the folid form. The ufe of this material for cafting fmall ftatues, medallions, and other ornaments, is well known. EARTHS.

Animal earth. The earth which enters into the compofition of the bones of animals and fhells of fifh is calcareous. In the former it is united with the phofphoric acid, and in the latter with fixed air.

Ponderous earth. Ponderous earth, or barytes, is not found very abundantly, or in large continued maffes, but chiefly in the vicinity of mines, or veins of metal. Its fpecimens are either aërated ponderous fpar, which has been found at Alfton Moor, in Cumberland *, and confiderably refembles alum, but is of a ftriated texture: or vitriolated ponderous earth, either in the form of a tranfparent fpar or an opake earth; of a white, grey, or fawn colour; frequently of no regular figure, but often in the peculiar figure of a number of fmall convex lenfes fet edgwife in a ground. The opake fpecimens have been called marmor metallicum, on account of their great weight; but the Englifh miners call it cawk. Moft fpecimens of this earth are above four times the weight of an equal bulk of water, which conftitutes an obvious difference between this and calcareous earth, which is little more than twice that weight: they are

Ponderous fpar, or marmor metallicum.

* Analyfed by Dr. Withering. See Phil. Tranf. vol. lxxiv. Mr. Watt, jun. in the third volume of the Manchefter Memoirs, gives reafons for concluding that this fpecimen came from the lead mine of Anglezark, near Chorley, in Lancafhire, where it is plentifully found. He obferves that this is the only mine in England which is known to afford it. It has alfo been found in the mines of Strontion and Dunglafs, near Dumbarton, in Scotland.

fcarcely,

EARTHS.

fcarcely, if at all, foluble in water. The liver ftone, or lapis hepaticus, contains about one third part of this earth.

To obtain pure ponderous earth.

If ponderous fpar be fufed with about twice its weight of fixed alkali, its acid will unite with this laft, and form a falt, which may be wafhed off by water, the ponderous earth remaining behind in combination with fixed air. This may be deprived of its fixed air by a ftrong heat, which converts it into a ftate perfectly refembling quick-lime in tafte, and exhibiting fimilar phenomena with water.

Native aerated ponderous earth.

The natural aërated ponderous earth differs from that produced by art, in the circumftance that it contains no water; and to this it feems to be owing that it does not lofe its fixed air by mere heat.

This earth differs from lime.

Though this earth refembles lime in feveral refpects, yet its combinations differ from thofe of the latter, both in weight, and fo many other refpects, as evidently fhew that there is no reafon to confider them as one and the fame fubftance. It is combinable with acids.

Ponderous earth fuppofed to be metallic

From feveral properties in which ponderous earth has been obferved to refemble metallic fubftances, it has been fufpected to be of that clafs: but this fufpicion has not yet been verified by experiment.

Magnefia.

Moft of the native fpecimens of magnefian earth are remarkable for a certain foapy or greafy feel. Of thefe the moft common are, fteatites, of a greenifh colour, and foft enough to be fcraped with the nail; foap rock; lapis ollaris, or Spanifh chalk, of a yellow or whitifh colour, but rarely black, rather harder than fteatites, and fo eafily wrought and turned, that pots

are

are made of it. Afbeftos, amianthus, and the Venetian and Mufcovy talc, are included in this genus. EARTHS.

Epfom falt.

The combination of vitriolic acid and magnefia is very foluble in water, in which it remarkably differs from the combinations of the fame acid with the calcareous or ponderous earths. This compound is known by the name of Epfom falt, and is found in fome waters; but is moft frequently obtained, for commercial purpofes, from fea water, after the common falt has been extracted by evaporation.

Mild magnefia.

If mild volatile alkali be added to a folution of Epfom falt, the alkali unites with the acid, and part of the earth falls to the bottom, combined with fixed air, which, when well wafhed, is mild magnefia.

Pure magnefia.

Mild magnefia is a light impalpable powder, of a white colour; and forms a pafte with water, which has not much cohefion. Heat drives off its fixed air, and renders it fomewhat harfher to the feel; but not cauftic, nor foluble in water, like lime. Its tafte is very flight in either ftate. The ftrongeft heat does not affect it, if pure. Acids diffolve it, but alkalis fcarcely affect it in the dry way.

Union of earths by fufion.

As the various compounds of bodies ufually poffefs properties very different from thofe of their principles, it is accordingly found that the earths, though infufible alone, are not fo when mixed together. The calcareous earth is found to be the folvent of other earths, for they are all rendered fufible by a proper proportion of it. And thefe compounds of two earths will diffolve ftill more. So that though one hundred parts of lime will diffolve very little filiceous earth; yet a compofition of one hundred of lime with fifty of magnefia,

EARTHS.

magnefia, will diffolve one hundred of filiceous earth; and this laft compound will take up more magnefia than the mere calcareous earth could have done. Any three of the earths, in equal parts, will vitrify into a perfect glafs, provided calcareous earth be one among them.

Suppofed reduction of the earths.

It has lately been afferted, upon good authority, that the argillaceous, calcareous, ponderous, and magnefian earths were reduced to the metallic ftate by ftrongly heating them with charcoal*. But however it may be probable from analogy that fuch reductions may be within the limits of poffibility, it is at prefent generally underftood that the metallic matter obtained in thefe experiments confifted of iron afforded by the crucibles made ufe of.

The new earths.

We fhall frequently have occafion to treat of the five ancient earths, as their various combinations prefent themfelves to our notice: but the three lately difcovered earthy fubftances not having been fubjected to experiments, except in the laboratories of the difcoverers, will not again come under difcuffion in the prefent work. On this account therefore it will be proper to fpeak rather more fully refpecting them than the preceding, and likewife to enter more minutely into the defcription of proceffes than we might otherwife do in this early part of our work.

Characters of adamantine fpar:

A ftone has been within a few years brought from the Eaft, which has received the name of Adamantine Spar. Two varieties are known †. The firft

* Journal de Phyf. 1790.

† Extracts from the Memoir of M. Klaproth. Annales de Chimie, i. 183.

comes

comes from China; it is cryſtallized in ſix-ſided priſms, without pyramids, varying in their length from half an inch to one inch, and in breadth near one inch; its colour is grey, of different ſhades. Whole pieces are opake, but thinner fragments are tranſparent: its texture is ſparry, and it breaks with a poliſh. The ſparry texture produces a ſlight ſtriated appearance on its ſurface: its hardneſs is ſo great, that it not only cuts glaſs like a diamond, but it marks rock cryſtal, and other hard ſtones: its ſpecific gravity is 3.7 . 0, and in ſome ſpecimens as high as 4 180. Small grains of magnetic calx of iron are ſometimes diſſeminated through this ſtone. EARTHS. —from China.

The ſecond variety is whiter, more decidedly ſpathoſe in its texture, and the grains of calx of iron are ſmaller, and merely adhere to its ſurface. It is called corundum at Bombay*. At Madras it is known by the name of grinding ſpar. —from Bombay.

M. Klaproth attempted the analyſis of this ſtone by keeping it in fuſion with fifteen times its weight of cauſtic mineral alkali in a ſilver crucible for five hours; then adding boiling water, filtering and ſaturating the alkali with an acid, which conſequently threw down that portion of earth which had combined with the alkali. The undecompoſed part was repeatedly digeſted with concentrated boiling acids. The ſtone was not completely decompoſed till after twelve repetitions of this proceſs; and it was found to conſiſt of two parts clay, and one of an earth not ſoluble by fuſion in alkalis, nor acted upon by acids. It differs there- Analyſis of adamantine ſpar. Peculiar earth.

* Various ſpecimens have been found in France. See De Morveau in the Annales de Chimie, i. 188.

EARTHS.

therefore from filiceous earth, as well as from the four other foluble earths.

Characters of the jargon of Ceylon.

The fame chemift examined the jargon of Ceylon by proceffes nearly fimilar*. The colour of this ftone is pale, of a yellowifh green, inclining to red; forming upon the whole a kind of fmoky grey tinge. Its regular figure is that of a four-fided prifm, terminated by two obtufe pyramids, compofed each of four ifofceles triangles. Its fpecific gravity exceeds that of any other ftone, being 4.615.

Pieces of this ftone being ignited, thrown into water to render it lefs coherent, and then levigated upon porphyry, were fufed in the filver crucible, with a large proportion of cauftic fixed alkali. The folution was treated with water and with marine acid, which took up a fmall part, and left a refidue, which was again fufed with alkali, and treated as before. After feveral repetitions of this procefs, the whole was diffolved. By faturating the acid with mild vegetable alkali, the earthy matter was thrown down. Digeftion of part of this precipitate with marine, and part with vitriolic acids, indicated, after a due application of chemical methods, a confiderable portion of filiceous earth, with a minute quantity of iron and nickel, and a much larger proportion of an earth which remained fufpended on account of its folubility in acids. This

Peculiar earth.

earth was found to differ in its properties from every other yet known: its folubility fufficiently diftinguifhes it from filex. When precipitated by mild alkali, it did not become effervefcent, like lime or magnefia;

* See the Memoir at length in the Journal de Phyfique for March 1790.

neither

EARTHS.

neither did it, like them, form felenite or Epfom falt with vitriolic acid. It did not form alum with the vitriolic acid, as clay does. It differed effentially from ponderous earth, in its not being precipitable by the Pruffian alkali; and in forming a falt with vitriolic acid, which was exceedingly different from ponderous fpar. This earth was not foluble either in microcofmic falt, or in mineral alkali, when treated by the blow-pipe; but borax diffolved it. The jargon was found to contain in the hundred parts $31\frac{1}{2}$ filex, $\frac{1}{2}$ calx of iron containing nickel, and 68 of this peculiar earth.

Mineral from New South Wales:

A mineral from New South Wales was put into the hands of Mr. Wedgwood by Sir J. Banks*. It confifted of a mixture of fine white fand, a foft white earth, fome colourlefs micaceous particles, and a few black ones, refembling black mica or black lead. Mr. Wedgwood made fome experiments upon it, but does not appear to have completely analyfed the mafs, moft probably on account of its fmall quantity.

—fubjected to experiments.

Neither the nitrous nor vitriolic acids, concentrated or diluted, hot or cold, were found to take up any thing from this mineral which could be precipitated by alkalis; excepting that the ftrong vitriolic acid, by due management, indicated a minute portion of clay. But the marine acid, by digeftion near its boiling heat, acted on it with frequent explofive burfts, and took up about one fifth of the whole. The crude mineral, pulverifed and calcined, loft its blacknefs, and one fourth of its weight, but was found to be as difficult of folution as before. Water added to the marine

* Wedgwood in the Philof. Tranf. for 1790, page 306.

folution,

EARTHS.

White earthy matter.

folution, threw down a white precipitate; and the feparation was fo complete, that, after an addition of eight or nine times the whole bulk of water, there remained nothing in folution that alkali could precipitate. This white matter was infoluble in water, and alfo in the nitrous or vitriolic acids, and in alkaline folutions. Strong marine acid took it up as before, by the affiftance of the fame degree of heat. A certain precife quantity of nitrous acid added to the marine folution, kept the white matter fufpended, even when diluted with water. Strong vitriolic acid did not throw down the white matter from the marine folution; but when the quantity added was nearly equal to that of the folution, part of the marine acid was extricated in white fumes, with effervefcence. The mixture, heated nearly to boiling, becomes tranfparent, and continues fo in the cold. This folution is alfo precipitable by water, and the precipitate is foluble in marine acid.

Marine folution of the white matter:

The faturated marine folution does not cryftallize by evaporation, but affords a deliquefcent mafs, which is not corrofive, and parts with its acid in an heat near ignition. Pruffian alkali does not precipitate the marine folution; but all the alkalis, whether mild or cauftic, occafioned copious precipitations, which were foluble in marine acid, and thence precipitable by water in the original ftate.

—fufibility.

This white precipitate is much more fufible than any of the other fimple earths. In a heat between 142 and 156 degrees of Wedgwood's thermometer, which is nearly as high as is produced in a fmall air furnace, it melted in contact with clay, with flint, with chalk, with lime, with magnefia, with pure ponderous earth, and

and with ponderous ſpar, in ſeveral different experiments. In a hole ſcooped in chalk it ran into a ſmooth whitiſh opake bead, not at all adherent to the chalk itſelf; and in a cavity in charcoal it likewiſe fuſed, but did not ſeem to undergo any revivification. Part of this was ſoluble in boiling marine acid, and precipitable by water, as at firſt; but an accident prevented the determination whether the whole was ſoluble.

Peculiar earth.

It appears proper therefore to conſider the white matter as a new earth; directly ſoluble in no menſtruum but marine acid, or perhaps its compounds; not cryſtallizable in this combination; precipitable by water, and not by the Pruſſian alkali; parting with its acid in a heat below ignition; and fuſible in a degree of heat not very much exceeding that required to melt caſt iron.

Other parts of the mineral.

The black ſubſtance which ſeems to have compoſed about one-fifth part of the crude mineral, was found to reſemble plumbago in its leading properties, but its reſidue did not appear to be iron. The remaining three-fifths of the mineral which reſiſted the humid attacks in Mr. Wedgwood's experiments, was probably ſilex; but he does not ſpeak of any direct examination of its properties by fuſion with alkalis, the ſparry acid, or otherwiſe.

New mineral from Strontion.

In the ſecond part of the Philoſophical Tranſactions for 1794, there is an account of a mineral ſubſtance called ſtrontionite, from the place Strontion in Scotland, where it is found in granite rocks, accompanied by galena and witherite, by which laſt name I ſuppoſe

EARTHS.

Mr. Schmeiſſer, the author of the analyſis, means the native aërated ponderous earth.

External characters of ſtrontionite.

In all the ſpecimens this author had ſeen he could not diſcover any regular cryſtallized figure. The ſpecimen which he ſubmitted to experiment was in ſolid maſſes, apparently compoſed of long fibres, cloſely adhering together, and diſpoſed in radiations; its colour was an aſparagus green, deeper towards the center of the maſs. When broken, the ſurface was a little ſhining in certain directions; the fragments rather bar-like, and ſomewhat brittle.

Some ſpecimens exhibit only light ſhades of this colour, and appear to be compoſed of long thin bars, which are often ſeparated from each other towards the extremity.

The ſpecimen examined was ſemi-tranſparent; but the moſt of it rather inclining to opake. A hard knife ſcratched it, but it could not be ſcraped. Its ſpecific gravity was 3.586 at 60° degrees of temperature.

The firſt experiments, which pointed out a diſtinction between the baſis of this ſtone and the ponderous earth of Scheele, were made, by Dr. Crawford's deſire, by his aſſiſtant Mr. Cruikſhank, and were afterwards repeated by himſelf. The account of theſe is inſerted in the ſecond volume of the Medical Communications, by reference to which Mr. Schmeiſſer very properly does juſtice to the original diſcoverers.

Analyſis of ſtrontionite by M. Schmeiſſer.

Mr. S. found, 1. That the powder of ſtrontionite was not acted on by boiling water :—2. Nor by the vitriolic acid.—3. But the nitrous and marine acids ſeverally

Characters and habitudes of ſtrontionite.

ſeverally and entirely diſſolved it, with ſtrong effervefcence: the elaſtic fluid which eſcaped was pure fixed air. 4. Diluted vitriolic acid, added to the diluted nitrous and marine ſolutions, threw down a white precipitate. 5. Before the blow-pipe, a piece of the ſtrontionite did not crackle nor ſplit aſunder, nor did it melt, even when expoſed to white heat; but diſcovered a very bright phoſphoreſcent light, became more brittle, loſt its greeniſh caſt, and then was partly ſoluble in water. A long continuance of the white heat deprived it of very little of its weight, and it ſtill efferveſced with acids. 6. With borax and with ſoda it melted with ebullition; but neither a blue nor a green colour was exhibited by fuſion with the former. 7. Fluid volatile alkali did not extract any blue colour from the powdered ſubſtance, nor when added to the acid ſolutions. The ſolutions in the marine and nitrous acids were colourleſs. A piece of paper, dipped in the nitrous ſolution, burned with a red flame. 8. The Pruſſian alkali, added to a ſaturated ſolution, threw down a very ſlight quantity of blue precipitate. 9. Acid of ſugar, added to the diluted ſolution, afforded a very ſlight precipitate. 10. The remaining liquid of the foregoing experiments was mixed with vitriolic acid until no more precipitate took place, after which the remaining filtered liquor afforded no earth when purified pot-aſh was added to ſaturation. 11. The ſaturated nitrous ſolution afforded cryſtals by evaporation, which were permanent in the air, and exhibited triangular and ſexangular plates. 12. The ſaturated marine ſolution exhibited on evaporation long ſix-ſided priſms, which

I 2 have

EARTHS.

Analyfis of ftrontionite.

have the broad alternating with the narrow fides, and terminate in obtufe trihedral pyramids. This was obferved by Dr. Crawford, who alfo found that the falt formed of the fubftance with acids diffolved in water produced five times more cold than the falt from the barytes in the fame acid: that the falt formed by marine acid and this fubftance was much more foluble in warm water than in cold, whilft the muriat of barytes is nearly as foluble in cold as in warm water: that one ounce of diftilled water diffolves three times as much of the muriat of ftrontionite as of the muriat of barytes, which makes a diftinction between the bafis of this fubftance and the barytes. 13. Nitrous acid added to the marine folution of ftrontionite occafioned a decompofition. 14. The earth was procured in a diftinct ftate by folution in marine acid, precipitation by diluted vitriolic acid, fubfequent drying and decompofition by means of heat with purified pot-afh, wafhing with water, and calcination. The quantity of fixed air contained in this earth was then proportionally afcertained by folution in acid. Mr. Schmeiffer then found that a hundred grains of fpecific vitriolic acid, by which I fuppofe he means the particular acid he made ufe of, required 133 grains of the pure earth for faturation; but that 150 grains of pure ponderous earth were required for the fame purpofe: that 100 grains of nitrous acid required 94 grains of this earth, but 120 grains of the ponderous earth for its faturation; and that 100 grains of marine acid required 56 of this earth, but 96 of the ponderous.

Conclufions from the analyfis of ftrontionite.

Hence Mr. Schmeiffer concludes, 1. That the native mineral contained no faline matter:—2. That it contained

EARTHS. Strontionite.

contained fixed air:—and 3, an earth fimilar to the ponderous earth in its habitudes with the vitriolic acid. 4. No water of cryftallization. 5. No cobalt nor copper. 6. A fmall portion of iron. 7. Some calcareous earth. 8. No argillaceous nor magnefian earth:—and 9. That the earthy bafis is of a different nature from ponderous earth.

In order to afcertain the quantity or proportion of component parts of this fubftance, he diffolved 100 grains in acid, which yielded 30 grains of fixed air. Half a grain of calcareous earth was precipitated by acid of fugar, and the remaining folution yielded by decompofition 68 grains of the peculiar earth which may be called Strontion earth. The remaining weight may be accounted for from the fubftance which gives it the colour, which from comparative experiments Mr. Schmeiffer fuppofes to be phofphorated iron and manganefe.

The fubftance with which it was accompanied was cryftallized in fix-fided prifms, with pyramids, colourlefs, femi-tranfparent, rather opake towards the bafis, and lefs hard than the other fubftance. By analyfis it was found to contain 70 grains of ponderous earth, 15 grains of fixed air, and 12 of calcareous earth.

CHAP. V.

OF THE SIMPLER SALTS; NAMELY, ALKALIS AND ACIDS.

ALKALIS.

Characters.

THE alkalis are three in number; the vegetable, the mineral, and the volatile alkali. Of theſe the two former are diſtinguiſhed by the general appellation of fixed alkalis. The general properties of fixed alkalis are—1. They change the blue ſyrup of violets to a green. 2. Their taſte is peculiar, and diſagreeably cauſtic, even when diluted with water. 3. They have a ſtrong attraction for water, with which they unite in all proportions, and even attract it in ſufficient quantities from the atmoſphere to become fluid. 4. They combine with acids by a ſtronger affinity than is poſſeſſed by moſt other ſubſtances, at a moderate temperature. 5. Moſt inflammable ſubſtances are acted upon by them. 6. They melt in a moderate heat, and in a ſtronger heat they are volatilized. 7. In the dry way they diſſolve earths, and the calces of metals.

Vegetable fixed alkali.

The vegetable fixed alkali is found in ſome ſalts which may be ſaid to be of the mineral kingdom; but it is obtained for all the purpoſes of trade and ſcience from vegetable matters. Of this there are ſeveral kinds, which differ only in the reſpective quantities and nature of the impurities they contain. The cendres graveleés is a ſtrong alkali, made by burning the huſks of grapes and wine-lees. Pot-aſh is procured from

ALKALIS.

Methods of procuring the vegetable alkali.

from wood-ashes, and is very far from being pure. Most vegetables afford this alkali by burning them, and mixing their ashes with pure water; which, after decantation or filtering, may be evaporated, and will leave the salt behind. The purest is obtained by wrapping tartar in wetted brown paper, and placing the parcels in beds or strata alternately with charcoal in a furnace. The whole is then to be set on fire, and the fire continued till the blackening smoke ceases to rise. If the heat be too intense, the alkali will melt, and mix with the impurities of the coal; but when the process is well conducted, the parcels may be taken out entire. By lixiviation or solution in pure water, with subsequent filtration, evaporation, drying, and calcining in a low heat, the alkali is obtained very white, and contains a considerable portion of fixed air. This might be driven off by heat; but it is not necessary to be done in that way, as it would be attended with some danger of the salt corroding the vessel, and becoming less pure. The vegetable alkali is known in the shops by the name of salt of tartar; but most chemists in London sell the impure alkali of pot-ash by this name.

Purifying of alkalis.

It is not easy to purify the common vegetable alkalis met with in trade, and it is seldom attempted. The chemist is not under any necessity to employ his time in procuring the alkalis absolutely disengaged from all other matter, as they will be equally useful if kept in combination either with fixed air or with water; in which states the quantities may be more accurately ascertained by weight when used, than if pure; because their rapid attraction for water, in

ALKALIS.

the latter cafe, renders the weighing almoft impracticable.

Alkalis which contain fixed air, are called mild alkalis.

Alkali of nitre, called fixed nitre.

For very nice purpofes this alkali may be had from common nitre by deflagration. Nitre confifts of the alkali united with an acid. If the fineft prifmatic nitre be fufed, and made red-hot in a crucible, and charcoal be then added by degrees, a moft intenfe combuftion takes place, during which the acid principle of the falt is diffipated, and the alkali is left in combination only with fixed air. More charcoal muft be added, as long as it continues to produce the vivid flame; and the heat muft be raifed towards the end, in order that the decompofition of the laft portions of the nitre may be more completely effected. This falt has been improperly called fixed nitre; but there is no difference between the pure fpecimens of this alkali, whatever fubject it may have been originally obtained from.

Purification of fixed alkali.

Fixed alkalis may be had in a ftate of great purity by treatment with ardent fpirit*. The alkali is firft to be deprived of moft of its fixed air by boiling, with about its own weight of quicklime, in twelve parts of water; and the clear folution muft then be evaporated till it begins to be flightly confiftent. It muft then be mixed with the ftrongeft ardent fpirit; and part of the fpirit may be drawn off by diftillation. As foon as the retort has become cold, it is found to contain a folution of pure alkali in ardent fpirit, which floats

* Berthollet, in the Journal de Phyfique for 1786.

above

above another aqueous fluid, containing that part of the alkali in cryſtals which ſtill retains its fixed air, and alſo the earthy or metallic impurities of the alkali. The ſpirituous ſolution being decanted off, and evaporated on a ſand bath, affords cryſtals of pure alkali in groups of quadrangular pyramids, which are very deliqueſcent, and ſoluble both in water and ardent ſpirit, with the production of cold.

The vegetable alkali, in its uſual ſtate, deliqueſces in the air, and conſequently unites with water in all proportions. The ſtrong ſolution of this alkali is uſually called oil of tartar per deliquium. Its action on the ſkin produces a ſenſation or feel of greaſineſs, which has given occaſion to this appellation. But it may be had in permanent cryſtals, if enough of fixed air be added to its ſolution. Oil of tartar.

The mineral alkali in its obvious properties differs but little from the vegetable. Its attractions in general are leſs ſtrong, and the compounds it forms with other bodies are very different from thoſe produced with the vegetable alkali. It uſually contains enough of fixed air to render it much leſs attractive of water than ſalt of tartar. If the quantity of water containing ſalt of ſoda be diminiſhed to about two and a half times the weight of the ſalt; this laſt begins to ſeparate in cryſtals, which do not deliqueſce in the air, but become dry, and fall to powder, by the loſs of that portion of water which entered into the formation of the cryſtals. Mineral alkali.

The water which enters into the formation of the cryſtals of any ſalt, is called the water of cryſtallization; and ſuch ſalts as fall to powder by expoſure to the Water of cryſtallization. Effloreſcence.

ALKALIS.

the air, are said to effloresce: the pulverulent substance thus obtained is sometimes called an efflorescence.

Abundance of mineral alkali; in sea salt,

Mineral alkali abounds in vast quantities in the waters of the sea, where it forms half the weight of the common salt; and it is sometimes found in other natural combinations. The efflorescence, or saline matter, which hangs upon old damp walls, consists of this salt united to fixed air and water; and in many places in Asia and Africa it is collected at the surface of the earth.

—obtained by incineration.

The mineral alkali in trade is obtained by burning certain plants which grow on the sea shore. It contains several neutral salts in small proportions, which may be separated by crystallization; as the alkali, being the most soluble, remains suspended in water longer than the rest. Sea salt may be decomposed, and its alkali obtained alone, but not sufficiently cheap for common uses. Mr. Turner's process is said * to consist in mixing a quantity of litharge (or calcined lead) with half its weight of common salt; which, after trituration with water till it assumes a white colour, is left to stand some hours: after which a decomposition ensues, the alkali becoming disengaged with water, while the acid unites with the metallic calx. This last, by a proper degree of heat, produces a fine greenish yellow pigment, the sale of which is the chief object of the manufacturer.

Turner's process with common salt.

The fixed alkalis are still considered as simple substances with regard to the present state of our knowledge. It is suspected however that the fixed vegeta-

* Cronstedt's Mineralogy, by Magellan, vol. i. p. 336.

ble

ble alkali may confist of lime in combination with the fubstance called phlogisticated air; and that the mineral alkali is composed of magnesia, united to the fame fubstance. The reasons for these suppositions are: * A small quantity of common nitre is produced by exposing washed chalk for some months to the exhalations of putrid animal substances. The repeated distillation of soap affords volatile alkali, and this contains phlogisticated air. And a portion of magnesia has been obtained by repeated solutions and calcinations of mineral alkali.

ALKALIS.

Caustic solution of alkali:

Fixed alkalis, deprived of the fixed air they may contain, by boiling them for a short time with quicklime, which has a stronger attraction to the air, and becomes converted into chalk by the process, are then said to be caustic, because they act with such energy as to corrode and destroy animal substances. Soap lees is a solution of this kind; and the combination of a caustic alkali with fat, or oil, is well known by the name of soap. If one part of lime, and two of salt of soda, be boiled in twelve parts of water for a short time, and the filtered lixivium be evaporated till its specific gravity be about 1.375, or, which is the same thing, till a phial which would contain an ounce of water would contain an ounce and three eighths of the solution; the soap may be made by mere mixture of this lye with olive oil, in the proportion of one part of the former with two of the latter, in a glass or stoneware vessel. This mixture, being beat up from time to time with a wooden spatula, soon becomes consistent;

—or soap lees.

Soap.

* Thouvenel on Nitre. Chaptal's Elements of Chemistry, i. 181. Eng. transl. and the authors by him cited.

and

ALKALIS. and in feven or eight days it forms a very white and hard foap.

Manufacture of foap in the large way.

In large manufactories the lye is made no ftronger than to float an egg, when the workmen begin to form the mixture. To a part of the lye diluted they add an equal quantity of oil, which is fet on a gentle fire, and agitated. When the combination begins to take place, the reft of the lye is added, and the whole digefted by a gentle heat till the foap is formed. If well made, it is firm and white, and completely mixes with water, without exhibiting any greafe on the furface. Trials are made of it during the boiling; and the requifite additions, either of oil or alkali, are made as circumftances require.

Manufacture of glafs.

That beautiful product of human induftry, glafs, confifts of filiceous earth diffolved in an alkali. For this purpofe, nothing more is neceffary than to expofe a proper mixture of fand, flint, or cryftal, and fixed alkali, to heat in a furnace till they are incorporated together by fufion. Simple however as this procefs may appear, it is by no means an eafy operation to make a perfect glafs. If the materials be impure, and contain either metallic particles, or fuch as cannot be vitrified, the glafs will be coloured, or defaced with opake fpecks. If the proportion of alkali exceed two parts to one of earth, the glafs will be liable to alteration by the action of the air or faline fubftances, efpecially acids. If the fufion be not continued a fufficient time, the glafs will be imperfect for want of a fufficient combination of the materials; and no means have yet been found to prevent the lower part of the pots of glafs from containing a denfer glafs than the upper,

Difficulties.

upper, by the fubfidence of the heavier materials; a circumftance which produces the appearance of threads or veins in the work, on account of the different action of the feveral parts of the fame glafs on the rays of light. The management of the heat is alfo a material point; for every increafe of heat extricates bubbles of fome elaftic fubftance; and if the glafs be ufed during this effervefcence, it will abound with little cavities which injure its tranfparency. The imperfections of glafs are moft fenfibly felt in the conftruction of optical inftruments, efpecially thofe which are called achromatic.

Frit.

To prevent the fwelling, at the firft combination of the materials, they are previoufly mixed, and expofed for a confiderable time in a lower heat than is fufficient to convert them into glafs; by which management great part of the more volatile matters is diffipated. This imperfect combination is called frit, and is afterwards fufed by a ftronger heat. Glafs utenfils, unlefs very fmall, require to be gradually cooled in an oven. This operation is called annealing; and is neceffary to prevent their cracking by change of temperature, wiping, or flight accidental fcratches.

Manufacture of fal ammoniac.

The volatile alkali is moft commonly obtained from fal ammoniac. This falt was formerly imported from Egypt, where it is procured by fublimation from foot produced by burning the dung of camels. It is now made in great plenty for the purpofes of trade in Great-Britain. The component parts are volatile alkali, and the fame acid as enters into the compofition of fea falt, and is called the marine acid. The volatile alkali is obtained in an impure liquid ftate by the manufac-

ALKALIS.

turers, who diſtil it from bones, or ſoot, or any other ſubſtance that affords it. To this they add the vitriolic acid, and alſo common ſalt, in due quantities. The vitriolic acid firſt combines with the volatile alkali; but when the common ſalt, which conſiſts of fixed mineral alkali and marine acid, is added, a change of the principles takes place by double elective attraction. The vitriolic acid ſeizes the mineral alkali, and forms the new compound known by the name of Glauber's ſalt; while the marine acid unites with the volatile alkali, and forms ſal ammoniac. By evaporation of the water, theſe ſalts are ſeparated by cryſtallization, and the ſal ammoniac is ſublimed into cakes for ſale.

Volatile alkali: —obtained by the medium of chalk:

In order to diſengage the volatile alkali from ſal ammoniac by diſtillation, it is neceſſary to add ſome fixed ſubſtance which ſhall combine with and prevent the marine acid from riſing. Chalk and ſlaked lime are the bodies commonly uſed. If a mixture of two parts of chalk, and one of ſal ammoniac in powder, be expoſed to a ſand heat in a retort, with a receiver adapted, a change of principles by double affinity takes place. The chalk, which conſiſts of lime and fixed air, is decompoſed, and alſo the ſal ammoniac. The lime unites with the marine acid, and forms a fixed earthy ſalt, which remains in the retort; and the fixed air unites with the volatile alkali, and paſſes into the receiver, where it appears in the form of a white hard ſalt of a pungent ſmell. This is the mild volatile alkali, or ſal volatile of the apothecaries and perfumers. It is well known as a ſtimulant uſually put into ſmelling-bottles.

ALKALIS.

—obtained by the medium of lime.

When lime, or calcareous earth deprived of fixed air, is made ufe of, the decompofition takes place as before; but the volatile product has a very different appearance. It confifts, for the moft part, of a permanently elaftic or aërial fluid, which very readily combines with water, but may be confined in its elaftic ftate in veffels over mercury. Moft of this product was formerly loft, becaufe no more of it was detained in the veffels than had combined with the water which was driven over by heat from the materials in the retort. But by the ufe of an apparatus upon the principle of fig. 21, the air may be received and abforbed by water, without that great lofs which muft have arifen from the aërial fluid rifing long before the water, and the quantity of this laft being infufficient to retain it.

Alkaline air.

This permanently elaftic fluid is called alkaline air, and confifts of the pure volatile alkali itfelf. If fixed air be added to it, a white cloud is formed, confifting of mild volatile alkali, which precipitates; and the airs are either diminifhed or difappear, according to their relative proportions to faturate each other, or their refpective degrees of purity. With the marine acid air, hereafter to be treated of, which is the pure marine acid, it forms fal ammoniac in the fame manner. It unites with equal readinefs with the other acid airs. With water it forms the fluid volatile alkali commonly called fpirit of fal ammoniac with lime.

Decompofition and formation of volatile alkali.

The volatile alkali is decompofed and formed again in many chemical proceffes. Thefe, generally fpeaking, require a more intimate knowledge of chemical facts

ALKALIS. facts than the reader can yet be ſuppoſed to poſſeſs, for them to be ſpoken of at length in this place. It will therefore be ſufficient to obſerve, that the dimenſions of alkaline air are greatly enlarged by repeatedly paſſing the electric ſpark or exploſion * through it, or by igniting a piece of earthen ware in it; and it is by this means rendered incapable of being abſorbed by water, and becomes inflammable. By the admiſſion of vital air, and detonation, the inflammable part is condenſed, and the remainder is found to be phlogiſticated air †. Hence, as well as from other experiments, it is concluded that alkaline air conſiſts of four parts by weight of phlogiſticated, and one of inflammable air.

Characters of acids.

Acids are a genus of ſalts, which may be conſidered as leſs ſimple than the fixed alkalis; becauſe there are experiments which clearly ſhew that they may be decompoſed into principles ſtill ſimpler. Their properties are—1. They change the blue vegetable colours of ſyrup of violets, or tincture of litmus, to a red. 2. Their taſte is ſour, and in general corroſive, unleſs diluted. 3. Moſt of them unite with water in all proportions; and many have ſo ſtrong an attraction for it, that they cannot be exhibited in the ſolid ſtate. 4. They combine with alkalis by a ſtronger affinity than is poſſeſſed by moſt other ſubſtances to thoſe ſalts at a moderate temperature. 6. They act upon earths, and upon moſt inflammable ſubſtances and metals.

* Prieſtley, ii. 239. v. 218. vi. 189.

† Berthollet in Mem. Acad. Par. for 1785, page 324. Alſo Auſtin in Phil. Tranſ. vol. lxxviii. p. 387.

The

ACIDS.

Enumeration. Mineral acids.

The acids found in the mineral kingdom are—the vitriolic acid, known in commerce by the name of oil of vitriol; the nitrous acid, called ſpirit of nitre; the marine acid, called ſpirit of ſalt; the aërial acid, or fixed air; the acid of borax, called ſedative ſalt; the acid of ſpar, or ſparry acid; ſuccinous acid, or acid of amber; the acid of phoſphorus, or phoſphoric acid; the acid of tin; the acid of arſenic; the acid of molybdena; the acid of tungſten, or of wolfram.

Vegetable acids.

The vegetable kingdom affords the acids of lemons; of apples, or unripe fruits; of galls; of benzoin; of tartar; of ſugar, or ſorrel; the empyreumatic acid of tartar; the empyreumatic acid of ſugar, or mucilage; the empyreumatic acid of wood; the acid of camphor; the acid of cork; and the acetous acid, or vinegar.

Animal acids.

The animal kingdom affords the acid of milk; the acid of ſugar of milk; the acid of ants; the acid of Pruſſian blue; the acid of fat; the acid of the ſtone of the bladder; and the acid of ſilkworms.

Inflammable additions to acids.

When an inflammable ſubſtance is added to a ſtrong acid, the effects in general are, that the acid is rendered more volatile, and part flies off in an elaſtic form, which has various properties, according to the nature and properties of the acid, as will be hereafter ſhewn.

Theory

In the theory of phlogiſton, acids are ſuppoſed to contain that principle, and to be capable of uniting with it in various proportions. When they have received a larger proportion, they are rendered more volatile, and fly off in the elaſtic form; and when

ACIDS. Theory.

they have a lefs than the ufual proportion of it, they are faid to be dephlogifticated, and act more ftrongly on phlogiftic bodies. In the new theory, acids are fuppofed to confift each of a peculiar bafe united to vital air in a fixed ftate. If they act on a combuftible body, and become deprived of part of their vital air by its action, their conftitution is changed, and their bafe is more difpofed to fly off; but if by any means they obtain an over-proportion of vital air, their action on combuftible bodies is more efficacious.

Vital air a component part of acids.

Moft of the phlogiftian chemifts admit of the exiftence of vital air, as a component part of acids; a pofition which feems indeed to be as well eftablifhed upon facts as any part of the fcience of chemiftry.

Neutral falts.

Combinations of alkalis with acids are called neutral falts.

CHAP.

CHAP. IX.

OF METALLIC BODIES IN GENERAL.

METALLIC fubftances are very eafily diftinguifhable from all other bodies in nature, by their very great weight, and that opake fhining appearance which is called the metallic fplendour or brilliancy. Very few fubftances have half the fpecific gravity of the lighteft among the metals. They are all fufible, though at very different temperatures; and if the fufion be made in clofe veffels, they fix again by cold, without having fuffered any change but that of external figure, which muft be produced in all bodies which have been either liquefied or volatilized; namely, they affume the form of the veffel which contains them. Some of them may be extended confiderably by the hammer, without breaking them. This property is called malleability; and the metallic bodies which poffefs it are called entire metals, or metals, in contradiftinction to fuch as are more brittle, and are called femi-metals. Metallic fubftances are alfo called perfect and imperfect. The perfect are fuch as undergo no lafting change of their properties by any heat we can apply to them, at leaft in common furnaces. The imperfect metals, when expofed to a ftrong heat, with accefs of vital air, are changed, by a procefs fimilar to burning, and in fome of them with an actual flame, into a brittle dull fubftance called a calx, which is heavier than the metal it came from, though its fpecific gravity is not

CHARACTERS OF METALS.

Entire metals.

Perfect and imperfect metals.

Calces.

METALLIC SUBSTANCES.

Acids.

so great. Some are even converted into acids. If the calx of a metal be expofed to ftrong heat in a clofed veffel, with fome inflammable matter, it recovers its metallic ftate. This is called reduction or reviving of the metal.

Enumeration of metals.

All metals are imperfect except gold, filver, and platina. The imperfect metals are, mercury, lead, copper, iron, and tin; and the femi-metals are, bifmuth, nickel, arfenic, cobalt, zinc, antimony, manganefe, wolfram, molybdena, and uranite. The names arfenic, antimony, manganefe, wolfram, and molybdena, being ufed to denote the mineral fubftance from which the femi-metals are obtained, the femi-metals themfelves are diftinguifhed by the name of regulus of arfenic, regulus of antimony, and fo forth; though modern chemifts often ufe the fimple term to denote the femi-metal itfelf alone.

Regulus.

Freezing point of metals.

Metals, like other fufible bodies, have each a fixed temperature, or freezing point, at which they become folid. They affume a cryftallized figure in cooling, which is different in each, and may be feen by fufing them in melting-pots with a hole in the bottom, ftopped with a ftopper; for in this cafe, if the furface be fuffered to congeal, and the fluid metal beneath be fuffered to run out through the hole, the under furface of the remaining metal will be curioufly cryftallized. The fpecific gravity of metallic fubftances is very confiderably affected by the gradual or hafty cooling, or tranfition from the fluid to the folid ftate. Hammering renders them harder and more elaftic; but this effect is deftroyed by ignition.

Cryftallization.

Affinities.

The affinities of metals to each other are various.

Some will not unite at all; others mix very readily, and even combine together. On this property is founded the art of foldering; which confifts in joining two pieces of metal together by heating them, with a thin piece or plate of a more fufible metal interpofed between them. Thus tin is a folder for lead; brafs, gold, or filver, are folders for iron, &c.

METALLIC SUBSTANCES.

Solders.

Countries moft abundant with metal.

Mountainous diftricts, where the furface of the globe has been thrown up or difturbed, in remote ages, by earthquakes, volcanos, or other great convulfions of nature, are the moft abundant in metallic bodies. In digging into the bowels of the earth, the various materials are moftly found difpofed in ftrata or beds, which in plains lie level, but in mountains are inclined; whence it happens that in mountainous countries fome ftrata are often expofed to the day, which would elfe have been too deeply lodged to be come at by human art. It is in the ftratified mountains that metals are ufually found, moftly in a ftate of combination either with fulphur or arfenic, or in the ftate of a calx. They are alfo found, though lefs frequently, in the metallic or native ftate.

Ores. Veins. Mines. Matrix.

The combinations, or earthy bodies, which contain metals in fufficient quantity to be worth extracting, are called ores. Iron ore fometimes forms entire mountains; but in general the metallic part of a mountain is very inconfiderable in proportion to the whole. The ores run either parallel to the ftony ftrata, though far from having the fame regularity of thicknefs, or they crofs the ftrata in all directions. Thefe metallic ftrata are called veins. The cavity formed by art in the earth, for the extraction of metals or any other mineral bo-

 dies,

METALLIC SUBSTANCES.

dies, is called a mine. The ſtone wherein a metallic ore is uſually bedded, is called its matrix. Theſe are not peculiarly appropriated to any metal, though ſome ſtones more frequently accompany metals than others.

Operations for extracting metals from ores.

The general operations by which metals are obtained from ores are—1. The minerals are ſelected; and ſuch only are taken as from experience are known, by the external figure or appearance, to contain metal. 2. They are reduced to powder; and the lighter parts waſhed away, by means of water, in a ſhallow trough. 3. The volatile parts are diſſipated by the operation called roaſting. 4. The ores are ſmelted by throwing them into the midſt of the fuel of a furnace, with earthy ſubſtances which are diſpoſed to run into glaſs. In this operation, the glaſſy matter, called ſcoria, in ſome meaſure produces the effect of rendering the lower part of the furnace a cloſed veſſel; and the fuel revives the metal, which in the ore is uſually of the nature of calx. The revived metal being much denſer than the ſcoria, falls to the bottom, and is ſuffered to run out by proper openings. Theſe are the general operations, but they are not all neceſſary in all caſes; and the particular practice with the ſeveral ores of each metal, muſt vary according to the properties of the metal itſelf, and the different ſubſtances it is united with.

Aſſaying, or eſſaying.

The extraction of metals from ores, in the ſmall way, which is neceſſary to be made in order to aſcertain whether the ſpecimens are worth working, is called aſſaying or eſſaying. In theſe ſmall trials the fuſibility of the pounded ore is increaſed by an addition of black flux, which is an impure alkali, formed by by mixing two parts of tartar with one of nitre, and setting them on fire. Metallic ores may be very accurately assayed by solution and precipitation in the humid way. Humid way.

The theory of the calcination and reduction of metals, according to the system of phlogiston, is as follows:—Metals, like all other inflammable bodies, contain phlogiston united to a base. While the vital part of the air unites with the base, the phlogiston is disengaged, and leaves behind it the combination called a calx, which is heavier than the metal, because the air received exceeds the weight of the phlogiston disengaged.—In the antiphlogistic system, metals are considered as simple substances, which are converted into calces by their union with vital air, and are revived by heating them with any other matter which is more combustible than themselves; that is to say, which has a stronger attraction for vital air, at the temperature of reduction. Some of the maintainers of phlogiston admit that the vital air unites with that principle of inflammability, and composes a substance which combines with the base of the metal. Here the fact agrees with the statement of the antiphlogistians, but the explanation is less simple. Theory.

Most metals will uniformly mix with each other; and the specific gravity of the compound is seldom such as would have been deduced from the supposition of a mere mixture, or simple apposition of parts. Their fusibility is likewise greatly changed by mixture, and according to no certain rule yet discovered. Mixture of metals.

Mixtures of metals are frequently called alloys. But the word alloy, or allay, is mostly used to denote a Alloy.

 portion

METALLIC SUBSTANCES.

portion of metal which is added to the precious metals, gold or ſilver.

Solubility of metals in acids.

Metals are moſtly ſoluble in acids, with which they form ſalts. When a metal is added to an acid, the general effect produced is the ſame as would have ariſen from the addition of any other combuſtible ſubſtance to the acid. If an alkali or earth be added to a metallic ſolution, the metal falls to the bottom in the form of a calx. But if a metal which has a ſtronger affinity with the acid than the metal already diſſolved has, be added to ſuch a ſolution, the former metal will fall to the bottom in its metallic ſtate, and the latter will be diſſolved without cauſing any of the eſcape of elaſtic fluid, and other appearances, which would have taken place if it had been applied to the mere acid; notwithſtanding which, the latter metal, if precipitated by an incombuſtible ſubſtance, ſuch as an alkali or earth, will be in the ſtate of a calx.

Precipitation.

Inferences.

It is evident, from theſe facts, that the action of acids upon metals is ſimilar to that of heat with acceſs of vital air; and of courſe may be accounted for, upon both the theories of chemiſtry, in the ſame manner as combuſtion itſelf. According to the original theory, when an acid acts upon a metal, it unites with the baſe of the metal, and expels the phlogiſton; which either riſes alone, in the form of inflammable air; or, combining with the acid itſelf, forms an acid air, or volatile acid. If an alkali be added, the calx falls down, combined with air, which it obtains either from the alkali or the acid; but if a metal be added, the phlogiſton of this laſt, uniting with the calx of the former, revives it, and it falls down in its metallic ſtate. The new theory

Original theory.

theory may be applied as follows: When a metal is added to an acid, it attracts vital air either from the acid itſelf or from the water. If the former, the acid itſelf is decompoſed; and its baſe, combined with an under proportion of vital air, ariſes in the form of volatile acid, or acid air. But if the latter, the water itſelf is decompoſed, its vital air combining with the metal, and its inflammable air flying off: in this caſe, the acid is ſuppoſed to do nothing more than hold the calx in ſolution, and by that means facilitate the action of the water, which would be much leſs effectual if the calx were ſuffered, on account of its inſolubility, to remain upon and defend the ſurface of the metal; which, by reaſon of its inſolubility in mere water, it would not fail to do, if the acid were not preſent.

METALLIC SUBSTANCES. New theory.

Precipitation of metals by metals.

Metals are precipitated by each other in the ſame order, or nearly ſo, in all acids. Hence it is inferred, that this effect is produced by the reaction of ſome common principle, either of the metal or of the acids. In the old theory, a metal which has a ſtronger attraction for phlogiſton, will take that principle from another metal which holds it more weakly; and of courſe the latter will cauſe the former to be precipitated in its metallic form. In the new theory, a contrary tranſition of vital air from the acid produces the ſame effect: for if a metal has a ſtronger attraction for vital air than is exerted by another metal already in ſolution, it will deprive this laſt of it, and cauſe it to fall down in the metallic ſtate.

Limit of ſolution in acids.

Acids diſſolve metals only in their calciform ſtate; and there is a certain limit near which the ſolution is

beſt

METALLIC SUBSTANCES.

best performed. If an acid be of such a nature as to be incapable of calcining a metal, it will not dissolve it, though the same acid would dissolve the calx if presented to it; and if the calcination be carried on too far, the calx will likewise be insoluble. To explain this according to the two theories, it may be observed, that acids calcine metals by virtue of their attraction for phlogiston, and suspend the calx by virtue of the same power exerted on the remaining portion of phlogiston, of which they cannot in general divest the calx; consequently, if the calx be divested of this portion, it will be insoluble. Or, in the other theory, the simple metal attracts as much vital air from the acid as is sufficient to convert itself into a calx, but not enough to saturate it with that principle: it is therefore suspended, in consequence of its remaining weak attraction for the vital air of the acid. But if the calcination be complete, that is to say, if the affinity of the metal for vital air be perfectly satisfied, the remaining attraction of the metal for vital air will cease, and it will be insoluble.

Theory of solution.

Action of various substances on metals.

The direct action of alkaline salts upon metals is not considerable: sulphur combines with most of them readily in the way of fusion; and the combination of sulphur with an alkali, called liver of sulphur, is a powerful solvent of all metals except zinc. Nitre, heated with metals, acts in the same manner as it does with other inflammable bodies—it deflagrates, and the metals become calcined. The perfect metals resist the action of nitre.

BOOK

BOOK II.

PARTICULAR CHEMISTRY.

SECTION II.

CONCERNING THE MINERAL ACIDS, AND OTHER MINERAL BODIES WHICH ARE CONVERTIBLE INTO ACIDS.

CHAP. I.

OF SULPHUR, VITRIOLIC ACID, AND THE COMBINATIONS THEY FORM WITH OTHER BODIES.

SULPHUR, or brimſtone, is a well-known hard, brittle, inflammable ſubſtance, of an opake yellow colour. It is found more or leſs pure in the neighbourhood of volcanos, where moſt probably it is always expelled from ſome previous ſtate of combination by the heat of ſubterraneous fires. It is a very common ingredient in a great variety of minerals and ores; but it is extracted for ſale chiefly from a ſtone called pyrites. This ſtone is often of an irregular globular figure; and, when broken, is found to have a radiated texture, the fibres uſually converging towards a centre. Their great weight, and the ſhining golden colour

SULPHUR.

Pyrites.

SULPHUR. Pyrites.

colour of ſome ſpecimens, often lead the ignorant to ſuppoſe them rich in precious metal. The contents of the pyrites are various; but the kind here ſpoken of contains from one ſixth to one third of its weight of ſulphur, one eighth to five eighths iron in a calcined ſtate, and the reſt clay and ſiliceous earth. They give fire plentifully with the ſteel; whence their name is derived. A moderate heat will expel the ſulphur from pyrites, as it is conſiderably volatile. In the large way, in Germany and Italy, the pyrites are put into earthen cucurbits, diſpoſed in a furnace in ſuch a manner that when the ſulphureous part melts, it runs into veſſels filled with water, and there congeals.

Diſtillation of ſulphur:

—ſublimation.

Sublimation is neceſſary to deprive ſulphur of the accidental impurities it may contain. This may be done in an earthen cucurbit ſet on a ſand bath, with a head properly adapted. The ſulphur riſes by a very gentle heat, little more than is ſufficient to melt it; and the fine ſublimate thus obtained is called flowers of brimſtone.

Action of water upon ſulphur.

Water has no immediate action on ſulphur. It is ſaid, however, to ſoften the outſide by long contact with it; and if ſulphur be heated nearly to ſuch a degree as to ſet it on fire, and then poured into water, it becomes ſoft, and partly tranſparent. In proceſs of time it recovers its original hardneſs and opacity. If ſteam of water be paſſed over ſulphur contained in a heated earthen tube, inflammable air is extricated either from the ſulphur or the water, and comes out at the end of the tube*. The experiment is troubleſome on account of the ſulphur ſubliming.

* Prieſtley, vi. 150.

The

The combinations of ſulphur with earths or alkalis are called hepars, or livers of ſulphur, from their colour. There is no perceptible action between ſulphur and ſiliceous earth. Argillaceous earth has very little action upon it in the direct way; but lime unites readily with it. If freſh quick-lime and flowers of ſulphur be mixed, and water be added a little at a time, the heat of the lime will be ſufficient to produce the combination. On addition of more water, it becomes reddiſh, and emits a fetid ſmell of rotten eggs, which is common to all the hepars. The more cauſtic the lime, the deeper the colour of the hepar. The pure fixed alkalis decompoſe calcareous hepar, by virtue of their ſtronger affinity to the ſulphur: and any acid whatever decompoſes it, by attracting the lime; the ſulphur at the ſame time falling to the bottom in the form of a ſubtle powder, formerly called magiſtery of ſulphur.

Combination of ſulphur: with lime:

Pure ponderous earth boiled in water with ſulphur, has but little action upon it: but in the dry way, when ponderous ſpar, or the combination of vitriolic acid and ponderous earth, is ſtrongly heated in a crucible with charcoal, a coherent maſs is formed, which is ſoluble in water, with the ſmell and other hepatic characters; and if any acid be added which will form a ſoluble ſalt with the ponderous earth, a precipitate of ſulphur will be obtained.

—with ponderous earth:

If a ſmall quantity of magneſia, and an equal quantity of flowers of ſulphur, be incloſed in a veſſel perfectly filled up with diſtilled water, and well ſtopped, and then expoſed to heat by immerſion in boiling water for ſeveral hours, a combination will take place, and

—with magneſia.

SULPHUR.

and the water will contain a magnefian liver of ful-phur; from which the earth may be precipitated by the addition of an alkali, which will unite with the fulphur; or the fulphur may be precipitated by an acid, which will combine with the earth.

Combination of fulphur with fixed alkalis.

The fixed alkalis combine very readily with fulphur, either in the moift or dry way, whether they be in a pure or cauftic ftate, or combined with fixed air; though more ftrongly in the former than the latter cafe. If a folution of fixed alkali in water be boiled with half its weight of powdered fulphur, a combination takes place, and liver of fulphur is formed. Or, if equal parts of dry alkali and powdered fulphur be melted in a crucible, and poured out on a flat polifhed ftone, as foon as the fufion is complete, the combination will be of a liver colour, and is the folid hepar. If it be made with a pure or cauftic alkali, its colour is deeper, and its characteriftic properties more intenfe, than when a mild alkali is ufed. A folution of the folid hepar in water forms precifely the fame fubftance as the preparation made in the moift way.

Hepatic air.

The peculiar fetid fmell of the folid hepar when moiftened, or of its folution, is produced by the emiffion of a permanently elaftic fluid, called hepatic air. This fmell, when ftrong, is infupportable, and fuddenly deftroys animal life. Hepatic air is very foluble in water, which it converts into a ftate perfectly refembling that of the fulphureous mineral fprings. It renders fyrup of violets green, blackens the calces of lead and bifmuth, and the furface of filver. Vital air decompofes it, and caufes fulphur to be depofited. It

detonates

detonates with vital air when ſet on fire. It is not clearly aſcertained in what manner the ſulphur is ſuſpended in hepatic air. Sulphur, melted by the burning glaſs, in inflammable air over mercury, produces a fluid which has the properties of hepatic air; and * if inflammable air be paſſed through melted ſulphur, it becomes converted into hepatic air. As this air is not obtained from hepar unleſs water be preſent, it has been ſuppoſed to conſiſt of ſulphur volatilized, in combination with inflammable air, extricated by a decompoſition of the water; whoſe other component part, namely, vital air, is ſuppoſed to unite with the ſulphur. It is even aſſerted that the reſidue contains vitriolated tartar. Hepatic air.

Fluid volatile alkali has very little action on ſulphur; but a volatile hepar may be produced by the union of alkaline air with ſulphur in the vaporous ſtate. If equal parts of quick-lime and ſal ammoniac be mixed together with half a part of ſulphur, and diſtilled with the pneumatic apparatus (fig. 15 and 21), with a ſmall quantity of water in the receiver, a reddiſh yellow hepatic liquor will be obtained, which is the volatile hepar, and was formerly known by the name of the fuming liquor of Boyle; ſo called from its inventor, and from the white fumes it emits in the air. Volatile liver of ſulphur.

Sulphur combines with moſt metallic bodies in the dry way. Oils likewiſe diſſolve it, and form compounds called balſams. Balſams.

* Haſſenfratz in Phil. Tranſ. vol. lxxvii. p. 306.

When

SULPHUR.

Combustion of sulphur.

When sulphur is heated in an open vessel, it melts; and soon afterwards emits a blueish flame, visible in the dark; but which, in open day-light, has the appearance of a white fume. This flame has a suffocating smell; and has so little heat that it will not set fire to flax, and may even be suffered to play against the palm of the hand without any considerable inconvenience. In this way the sulphur may be entirely consumed. If the heat be still augmented, the sulphur boils, and suddenly bursts into a much more luminous flame; the same suffocating vapour still continuing to be emitted.

Volatile vitriolic acid.

The suffocating vapour of sulphur is imbibed by water, with which it forms the fluid called volatile vitriolic acid. If this fluid be exposed for a time to the air, it loses the sulphureous smell it had at first, and the acid becomes more fixed. It is then the fluid which was formerly called spirit of vitriol. Much of the water may be driven off by heat; and the dense acid which remains is the vitriolic acid, commonly called oil of vitriol: a name which was probably given to it from the little noise it makes when poured out; and the unctuous feel it has when rubbed between the fingers, produced by its corroding and destroying the skin, with which it forms a soapy compound.

Oil of vitriol.

Vitriol of iron.

The pyrites before mentioned, which consist, for the most part, of sulphur and iron, are found to be converted into the salt called vitriol of iron by exposure to air and moisture. In this natural process the pyrites break, and fall in pieces; and if the change take place rapidly, a considerable increase of temperature follows, which is sometimes sufficient to set the mass

SULPHUR.

mafs on fire. By conducting this operation in an accurate way, it is found that vital air is abforbed. The vitriol is obtained by folution in water, and fubfequent evaporation; by which the cryftals of the falt are feparated from the earthy impurities which were not fufpended in the water.

Diftillation of vitriol.

The vitriolic acid was formerly obtained by diftillation from vitriol of iron. When this falt is expofed to heat, the vitriolic acid comes over, at firft attended with a large quantity of volatile fulphureous vapour; and, towards the end, there is a production of pure dephlogifticated air. The acid which rifes laft has a concrete cryftalline form. The acid obtained in this procefs is black, and requires to be purified by a fecond diftillation, or rectification, in which the volatile fulphureous acid comes over, and leaves the denfe vitriolic acid behind.

Manufacture of vitriolic acid.

Moft of the vitriolic acid now ufed is produced by the combuftion of fulphur. There are three conditions requifite in this operation. Vital air muft be prefent, to maintain the combuftion; the veffel muft be clofe, to prevent the efcape of the volatile matter which rifes; and water muft be prefent, to imbibe it. For thefe purpofes, a mixture of eight parts of fulphur with one of nitre is placed in a proper veffel, inclofed within a chamber of confiderable fize, lined on all fides with lead, and covered at bottom with a fhallow ftratum of water. The mixture being fet on fire, and fhut up, will burn for a confiderable time, by virtue of the fupply of vital air which nitre gives out when heated; and the water, imbibing the fulphureous vapours, becomes gradually more and more acid, after repeated

VITRIOLIC ACID.

combuftions; and the acid is afterwards concentrated by diftillation.

Characters of vitriolic acid.

Pure vitriolic acid is colourlefs, and emits no fumes. It ftrongly attracts water, which it takes from the atmofphere very rapidly, and in large quantities, if fuffered to remain in an open veffel. If it be mixed with water, it produces an inftantaneous heat, nearly equal to that of ebullition. Its action upon all the earths except the filiceous, upon the alkaline falts, upon many metals, and almoft every other combuftible fubftance, is very ftrong.

Combination of vitriolic acid and clay.

With argillaceous earth it forms alum. This well-known falt has a peculiar auftere or aftringent tafte; is foluble in about fifteen times its weight of water, at the temperature of 60°, and in a much lefs quantity at higher temperatures; from which it may be feparated in the form of permanent cryftals. It fufes at a moderate heat, and froths up till its water of cryftallization is evaporated; at which period it has the form of a white friable fubftance, called calcined alum, which retains the greateft part of its acid when not too much heated; and may again be reftored to its original form by adding the water it had loft by the heat.

Preparation of alum.

Alum is not made for the purpofes of commerce by a direct combination of the vitriolic acid and clay, but is extracted from fubftances ufually called alum ores, which either are, or probably were originally, compofed of clay and fulphur. From fuch as contain the alum ready formed, as is the cafe with earths of this kind found in the neighbourhood of volcanos, it is extracted by lixiviation in water, and fubfequent evaporation. But other fubftances, fuch as pyrites and

alum

alum flates, require to be burned or expofed to the air and moifture for a time, before any alum can be had from them. Thefe proceffes convert the fulphur into vitriolic acid. Alum works have long been eftablifhed in Britain, and many other parts of the world. VITRIOLIC ACID.

The acid in alum is not faturated. If a folution of alum be boiled upon clay, a confiderable portion of the latter will unite with the falt, and form a combination which is much lefs foluble than the alum itfelf.

Vitriolic acid with lime, p. 104:

With calcareous earth the vitriolic acid forms gypfum, or plafter of Paris. This faline fubftance is plentifully found in nature; and is known by different names, according to its texture and external appearance. The lapis fpecularis and alabafter are of this kind. It requires about five hundred times its weight of water to diffolve it at the temperature of 60°, and has for that reafon been reckoned an earth. Its chief ufe has been already adverted to.

—with ponderous earth, p. 105:

With ponderous earth the vitriolic acid forms the ponderous fpar, or marmor metallicum.

—with magnefia, p. 106:

With magnefia it forms Epfom falt, which has a bitter tafte. This is foluble in its own weight of water, at the temperature of 60°; and by evaporation it is recovered in cryftals, which are difpofed to efflorefce, or become converted into a dry powder by expofure to air.

—with vegetable alkali,

With the vegetable alkali this acid forms a falt commonly called vitriolated tartar, which is foluble in about fixteen times its weight of water, at the temperature of 60°; and from which it may again be recovered by evaporation in the form of permanent cryftals.

VITRIOLIC ACID.

Vitriolic acid with mineral alkali:

With the mineral or marine alkali, the vitriclic acid forms Glauber's falt, which requires only three times its weight of water to diffolve it at the fame temperature. It is more foluble in hot than cold water; and may therefore be feparated from a hot faturated folution, either by cooling or by evaporation. Its cryftals are ufually large and well formed; but they lofe their water of cryftallization, which amounts to near half their weight, by expofure to the air, and fall into an efflorefcence, or white powder.

—with volatile alkali:

The combination of the vitriolic acid with volatile alkali, is called vitriolic ammoniac. It is foluble in twice its weight of cold or an equal weight of hot water; and affords cryftals either by cooling or evaporation, which are permanent, or flightly difpofed to attract moifture and deliquefce. Some chemifts affert that it is volatile, and others affirm the contrary. Upon examination, it would probably be found that the acid or alkali, or both, are decompofed by heat.

—with combuftible matter.

When any combuftible fubftance is added to the concentrated vitriolic acid, the fluid becomes black; and emits white vapours, which are of an exceedingly pungent fulphureous fmell; and, if received over mercury, are found to confift of a peculiar aëriform fluid, which is not condenfable into the fluid ftate except by a very great degree of cold*. It is foluble in water, which it converts into volatile vitriolic acid, of exactly the fame nature as that obtained by the combuftion of fulphur. Whence it follows, that the fumes of fulphur confift of this kind of air, rendered vifible by

Aeriform vitriolic acid.

Page 138.

* This was effected by M. Monge. See Fourcroy's Chemiftry, vol. i. p. xxxi.

the

the moiſture it meets and combines with in the atmo- ſphere. Boiling vitriolic acid acts upon moſt metals, and affords vitriolic acid air, and with ſome of them ſulphur; but with ſuch metals as it can act upon when conſiderably diluted, it affords inflammable air. When this acid is diſtilled from metals to dryneſs, the latter product is vital air.

VITRIOLIC ACID.

Sulphureous acid.

The ſulphureous or volatile vitriolic acid forms ſaline combinations with earths, alkalis, and metals; but its attraction to theſe baſes is much leſs than that of the vitriolic acid. Expoſure to the air for a length of time changes theſe ſalts into common vitriolic ſalts, in the ſame manner, doubtleſs, as it changes the ſulphureous acid into the common vitriolic acid.

Characters of vitriolic acid air.

Vitriolic acid air is heavier than common air; and, like every other permanently elaſtic fluid, except vital air and its compounds, it extinguiſhes combuſtion, and deſtroys animal life. If alkaline air be mixed with it, the airs combine, and form a beautiful white cloud, which becomes condenſed, and is found to be vitriolic ammoniac; at the ſame time that a yellow ſubſtance is ſeparated, which ſeems to be ſulphur. Water impregnated with this air may be frozen without parting with it; and if ſuch impregnated water be expoſed to heat for many days in a glaſs veſſel hermetically ſealed (that is to ſay, cloſed by melting its aperture with a blow-pipe), it depoſits ſulphur*.

Vitriolic acid converted into ſulphur.

The converſion of ſulphur into the vitriolic acid, and contrary-wiſe, of the acid into ſulphur, being effects of great importance in chemical theory; it became a deſirable object to perform the latter, in order

* Prieſtley, iv. 124.

VITRIOLIC ACID.

to confirm fuch reafoning as was adopted refpecting the former. As it is evident that fulphur becomes vitriolic acid by combuftion, it muft follow by analogy, from what happens in the revival or reduction of burned metals, or metallic calces, that fulphur might be revived from vitriolic acid, by expofing it to heat with fome more combuftible fubftance. A difficulty however prefented itfelf in this attempt, which was, that the vitriolic acid, being rendered volatile by the addition of a combuftible body, would elude the attempt to expofe it to a confiderable heat. This, no doubt, was the circumftance that directed the attention of the great founder of the theory of phlogifton (Stahl) to the neutral falts; in which the acid is not only highly concentrated, but combined with a more fixed body, namely, the alkali. He fufed equal parts of fixed alkali and vitriolated tartar in a crucible; to which he added half a part of powdered charcoal. This mixture being well ftirred together, and heated ftrongly for a very fhort fpace of time, was poured out, all fparkling, upon a fmooth ftone previoufly greafed. The compound, when cooled, was found to be a true liver of fulphur; from which, after folution in water, and precipitation by adding an acid, the fulphur was obtained.

Stahl's experiment for obtaining fulphur from vitriolic acid.

Electricity.

When the electric fpark paffes between two furfaces of vitriolic acid confined in a bended glafs tube, there is a production of vital air.

Recapitulation and theory.

Such are the principal facts relating to fulphur and the vitriolic acid; which, when confidered with a view to theoretical arrangement, are found to be more immediately connected than at firft view they may feem

to

VITRIOLIC ACID.

Theory.

to be. The combuſtion of ſulphur is of the ſame nature as every other combuſtion. Vital air is abſorbed, and the inflammable principle is ſuppoſed to be extricated. The ſulphur, thus deprived of its phlogiſton, and united to vital air, becomes an acid; which is not completely changed until, by ſubſequent expoſure to the common air, it has imbibed ſtill more of the vital part, and the remaining phlogiſton has been diſſipated. The decompoſition of pyrites is a phenomenon of the ſame kind, but is performed more gradually, and of courſe with the accumulation of leſs heat. The ſulphur of theſe combinations attracts the vital part of the air by an action which is ſuppoſed to be increaſed by the ſtrong tendency of the iron to combine with the acid that reſults from the union; the phlogiſton being diſſipated for the ſame reaſon. Inſtead, therefore, of a combination of iron and ſulphur, they become converted into vitriol, in which an acid is found: and as this proceſs conſiſts of the abſorption of vital air, and diſengagement of phlogiſton, it is a true combuſtion; with this only modification, that the heat is ſeldom extricated ſo rapidly as to produce the appearances of ignition and flame, but is conducted off by the ſurrounding bodies nearly as faſt as it is generated.

Decompoſition of pyrites.

Black vitriolic acid.

In the diſtillation of vitriolic acid from vitriol of iron, the acid is rendered black and ſulphureous from the iron, which was not completely dephlogiſticated or calcined during its original combination with the acid: for the phlogiſton of the iron is ſuppoſed, in this diſtillation, to unite with the acid, and form ſulphur; while the portion of the vital air which con-

VITRIOLIC ACID.

Theory.

tributed to convert that fulphur into acid, unites with the calx, and is afterwards driven off towards the end of the procefs. A cryftalline or concrete form of the acid is fometimes produced by its holding the vitriolic acid air in folution. If this be driven off by heat, the acid will be pure. Hence it is clear that the volatile vitriolic acid differs in fact from the pure vitriolic acid, in the circumftance that it holds fulphur in folution. And the vitriolic acid air is the fame acid with fulphur, but with much lefs water, if any.

Mutual action of vitriolic acid and combuftible bodies.

The change in the vitriolic acid produced by the addition of a combuftible fubftance, is explained with equal facility; for it is the reverfe of the inflammation of fulphur. The pure air of the acid is abforbed by the combuftible body; while the phlogifton of this laft unites with the bafe of the fulphur, and forms fulphur. This fulphur renders the acid volatile; and it comes over in the aërial form, together with water. If the combuftible body be of fuch a nature as to leave a fixed refidue, to which the laft portions of acid may unite after all the water is diffipated, fulphur will come over alone. Or if all the fulphur be driven off, either with the water or after it, the laft product will confift of the vital air which adhered to the refidue, or fixed calx of the combuftible body. When the diluted vitriolic acid acts upon a metal, and difengages inflammable air, the acid unites entirely, and without decompofition, to the calx, and the phlogifton flies off in the aerial form.

Liver of fulphur from vitriolated tartar.

An explanation nearly fimilar may be applied to the formation of liver of fulphur, when vitriolated tartar is fufed with an alkali and charcoal. Vitriolated tartar, consisting of vegetable alkali united to vitriolic acid, is decomposed by charcoal. This uniting with the vital air of the acid, at the same time that it communicates its phlogiston to the base, converts the acid into sulphur; the additional alkali serves only to assist the fusion of the original mass, and to prevent the dissipation of the sulphur by combining with it.

VITRIOLIC ACID. Theory.

Antiphlogistic theory.

Thus far we have admitted the inflammable principle in our explanation; and it must be admitted, if it can be shewn that sulphur contains it. We must confess however that this has not been proved; and that inflammable air has never been obtained directly from sulphur, except a small quantity, by passing steam of water over it when heated in an earthen tube *; in which case the original doubt presents itself, whether the air come from the sulphur or the water. The modern theory, which rejects phlogiston, accounts for the preceding facts simply by the absorption or extrication of vital air. Sulphur is taken to be a simple substance. The combustion of sulphur consists of the rapid combination of that substance with vital air; which, at the same time, gives out its heat as its capacity is diminished. A smaller proportion of vital air, with the sulphur, composes the volatile vitriolic acid, whether in the aërial form, or mixed with water: a larger dose forms the complete vitriolic acid. If a combustible body be added to vitriolic acid, this body becomes burned, or calcined, by uniting with part of the vital air of the acid; the remainder consequently has an over-proportion of sulphur, and therefore becomes volatile. If the absorption of pure air be suf-

Page 95.

* Priestley, vi. 150.

ficiently

VITRIOLIC ACID. Theory.

ficiently copious, the acid is reſtored to its former ſtate, and becomes ſulphur again. When the combuſtible body is metallic, the pure air may, in ſome caſes, be driven out by heat from the reſidue. And laſtly, when inflammable air is obtained by the ſolution of metals in the diluted acids, it is taken for granted that it ariſes from the decompoſition of the water, whoſe vital air, uniting with the metal, conſidered as a principal ſubſtance, calcines it; while the inflammable part flies off, and the acid does nothing more than diſſolve the calx, and by that action facilitates its formation.

Detonation of hepatic air.

The detonation of hepatic with vital air may be readily explained on either hypotheſis; whether it be ſuppoſed to conſiſt chiefly, if not entirely, in the combuſtion of the ſulphur, which muſt by that means be ſuddenly converted into vitriolic acid air; or ſimply of the inflammable air, while the ſulphur is depoſited.

CHAP.

CHAP. II.

OF THE NITROUS ACID, ITS COMPONENT PARTS, AND COMBINATIONS.

NITROUS ACID.

Production of nitre.

THE nitrous acid is obtained from the falt called nitre or falt-petre, which confifts of the acid itfelf united to the vegetable alkali. This falt is never found in confiderable quantities in nature, but is evidently produced by a concurrence of circumftances. The nitrous acid appears to be produced in all fituations where animal matters are completely decompofed, with accefs of air, and of proper fubftances with which it can readily combine. Grounds frequently trodden by cattle, and impregnated with their excrements; or the walls of inhabited places where putrid animal vapours abound, fuch as flaughter-houfes, drains, or the like, afford nitre by long expofure to the air.

Nitre beds.

Artificial nitre beds are made by an attention to the circumftances in which this falt is produced by nature. Dry ditches are dug, and covered with fheds, open at the fides, to keep off the rain: thefe are filled with animal fubftances—fuch as dung, or other excrements, with the remains of vegetables; and old mortar, or other loofe calcareous earth, this fubftance being found to be the beft and moft convenient receptacle for the acid to combine with. Occafional watering, and turning up from time to time, are neceffary to accelerate the procefs, and increafe the furfaces to which the air may apply. After a fucceffion of many months, more or lefs, according to the management of the operation,

NITROUS ACID.

in which the action of a regulated current of fresh air is of the greatest importance, nitre is found in the mass. If the beds contained much vegetable matter, a considerable portion of the nitrous salt will be common saltpetre; but, if otherwise, the acid will, for the most part, be combined with the calcareous earth.

Extraction of saltpetre.

To extract the saltpetre from the mass of earthy matter, a number of large casks are prepared, with a cock at the bottom of each, and a quantity of straw within, to prevent its being stopped up. In these the matter is put, together with wood-ashes, either strewed at top, or added during the filling. Boiling water is then poured on, and suffered to stand for some time; after which it is drawn off, and other water added in the same manner, as long as any saline matter can be thus extracted. The weak brine is heated, and passed through other tubs, until it becomes of considerable strength. It is then carried to the boiler, and contains nitre and other salts; the chief of which is common culinary salt, or the marine acid united to the mineral alkali, or sometimes to magnesia. It is the property of nitre to be much more soluble in hot than cold water; but common salt is soluble very nearly as much in cold as in hot water. Whenever, therefore, the evaporation is carried by boiling to a certain point, much of the common salt will fall to the bottom, for want of water to hold it in solution, though the nitre will remain suspended by virtue of the heat. The common salt thus separated is taken out with a perforated ladle; and a small quantity of the fluid is cooled, from time to time, that its concentration may be known by the nitre which crystallizes in it. When the fluid is sufficiently evaporated,

evaporated, it is taken out and cooled, and great part of the nitre ſeparates in cryſtals; while the remaining common ſalt continues diſſolved, becauſe equally ſoluble in cold as in hot water. Subſequent evaporation of the reſidue will ſeparate more nitre in the ſame manner.

Purification of nitre.

This nitre, which is called nitre of the firſt boiling, contains ſome common ſalt; from which it may be purified by ſolution in a ſmall quantity of water, and ſubſequent evaporation: for the cryſtals thus obtained are much leſs contaminated with common ſalt than before; becauſe the proportion of water is ſo much larger, with reſpect to the ſmall quantity contained by the nitre, that very little of it will cryſtallize. For nice purpoſes, the ſolution and cryſtallization of nitre are repeated four times. The cryſtals of nitre are uſually of the form of a ſix-ſided flattened priſm, with dihedral ſummits. Its taſte is penetrating, but the cold produced by placing the ſalt to diſſolve in the mouth is ſuch as to predominate over the real taſte at firſt. Seven parts of water diſſolve one of nitre at the temperature of 60 degrees; but boiling water diſſolves its own weight.

Decompoſition of nitre by heat.

If nitre be expoſed to a ſtrong heat, it melts, and becomes red hot; and the volatile product is found to conſiſt of fuming nitrous acid, a large quantity of vital air, and ſome phlogiſticated air; the alkali remaining behind, ſomewhat altered by a portion of the earth of the retort which it has diſſolved. Moſt other nitrous ſalts give out vital air by the ſame treatment. The extreme difficulty of aſcertaining the weights of aërial products, and of the fixed reſidues, renders it an embarraſſing

NITROUS ACID.

barraſſing taſk to ſhew by real experiment what happens in this operation among the principles of nitre.

Defiagration of nitre.

When a combuſtible body and nitre are brought into contact, either of them being previouſly heated red hot, the body is burned with great rapidity, no doubt by the vital air which the nitre affords by the heat; for the experiment ſucceeds in vacuo, and alſo when the bodies are ſurrounded by any aërial fluid incapable of maintaining combuſtion. This rapid combuſtion, effected by means of nitre, is called deflagration, when it is performed by a ſucceſſive burning of the parts of the body; or detonation, when the combuſtion of the whole is performed in ſo ſhort a time as to appear inſtantaneous. In this experiment it is remarkable that the combuſtion is maintained by vital air which is not in the elaſtic ſtate, but fixed in the nitre. Whence it ſhould follow, that either the vital air, or the combuſtible body, even in the fixed ſtate, has a great capacity for heat, of which it muſt contain a large quantity, on the hypotheſis of heat being matter. Or, if heat be a mere commotion, it will follow, that though the quantity of agitation produced by the ſudden coalition of particles, in the act of converting an elaſtic fluid into a denſe body, be ſuch as to produce a great effect in increaſing the temperature; yet the quantity is ſtill ſo conſiderable, when vital air and combuſtible matter unite even in their denſe ſtate, as to cauſe the moſt intenſe degree of ignition.

Detonation.

Invention of gunpowder.

This property of nitre has been applied to the production of a ſubſtance which has greatly affected the habits of human ſociety, particularly in thoſe wars which unfortunately their vices too often produce. The

The invention of gunpowder has totally changed the military fyftem of nations; and has probably fuppreffed much of that malice and inveterate rancour which actuate the minds of combatants who meet hand to hand, inftead of managing the inftruments of indifcriminate flaughter at a diftance. This deftructive powder is compofed of feventy-five parts by weight of nitre, fixteen of charcoal, and nine of fulphur, intimately blended together by long pounding in wooden mortars, with a fmall quantity of water. This proportion of the materials is the moft effectual; but the circumftance on which its effect more particularly depends is, the accurate mixture of the parts. Gunpowder is granulated by making the mafs into a ftiff pafte, and agitating it upon a wire fieve, which cuts it into fmall parts; and thefe being fhaken, or rolled in a barrel, take a rounded form by their mutual friction againft each other. When any grain of a heap of gunpowder is fet on fire, the detonation begins, and is propagated with amazing rapidity through the interftices of the grains; a large quantity of permanently elaftic fluid, confifting of one-third fixed air, and the reft phlogifticated air *, being at the fame time produced. The expanfion of the elaftic products is the caufe of the well-known effects of gunpowder. It is faid that gunpowder is much weaker for being granulated. If the grains be pulverized, it is certain that the effect is much lefs, on account of the inflammation being propagated more flowly; but the affertion may neverthelefs be true of powder which is newly made,

Compofition of gunpowder.

* Berthollet, in the Mem. Acad. Par. 1781, page 231.

NITROUS ACID.

and has never been grained. Gunpowder which has been fuffered to become damp, fcarcely ever recovers its former force ; moft probably becaufe the nitre, by a partial folution, becomes feparated from the mafs in more diftinct faline cryftals than before ; and the wetting, which is neceffary to the procefs of granulating, may weaken the powder in the fame way.

Fulminating powder.

When three parts by weight of nitre, two of mild vegetable alkali, and one of flowers of fulphur, are rubbed together in a warm mortar, they compofe a powder known by the name of fulminating powder. The effects of this powder, when fufed in a ladle, and then fet on fire, are aftonifhing. The whole of the melted fluid explodes with an intolerable noife ; and the ladle is commonly disfigured, as if it had received a ftrong concuffion downwards. A drachm of the powder makes a report as loud as a cannon ; but the noife of a few grains is fufficiently unpleafant in a room. It has very little effect, unlefs firft melted. A mixture of liver of fulphur with twice its weight of nitre, produces the fame explofion, though in lefs time ; whence it appears that the alkali and fulphur of the former preparation form a liver of fulphur ; and that the explofion, in all probability, arifes from the fudden extrication of hepatic air from the liver of fulphur, and vital air from the nitre, which burn the inftant they are formed.

Diftillation of nitrous acid.

If clay, bole, or alum, be mixed with nitre, and expofed to diftillation, the nitre is decompofed, and the acid comes over ; the attraction between itfelf and the alkali being weakened, partly by the attraction which the vitriolic acid ufually contained in thofe bodies has

has for its alkali, and partly by the attraction exerted between the same alkali and the siliceous earth of the clay. If strong vitriolic acid be added to nitre in a retort, the same decomposition takes place with the application of much less heat, by virtue of the superior attraction of the acid of vitriol to the alkaline base. NITROUS ACID.

Nitrous acid is usually yellow, and emits suffocating fumes of the same colour; but it may be rendered pure and colourless by a slight boiling in a retort. Aqua fortis is a weak spirit of nitre, and not remarkably pure. It usually contains some marine acid.

The assayers purify their nitrous acid by adding a small portion of the nitrous solution of silver. This metal unites with the marine acid it may contain, and falls down in the form of an insoluble compound. Care must be taken to avoid adding too much.

This acid, in combination with calcareous earth, forms a salt whose crystals deliquesce by exposure to the air. It is soluble in twice its weight of cold, or its own weight of boiling water. With ponderous earth it forms a salt of difficult solubility. With magnesia it forms an acrid bitter salt, which is very soluble in water, and deliquescent in the air. With clay it forms an austere salt of difficult solution. None of these have yet been applied to any use. Nitrous acid; with lime: —with ponderous earth; magnesia: —and clay:

With the mineral alkali this acid forms a salt called quadrangular nitre, from the usual form of its crystals. About three times its weight of water is required to hold it in solution in a mean temperature, and it is scarcely more soluble in hot water. Its properties resemble those of common nitre; but it is —with mineral alkali:

NITROUS

less fit for making gunpowder, because it attracts the humidity of the air.

—with volatile alkali.

The nitrous acid, in combination with the volatile alkali, forms nitrous ammoniac; a salt which slightly attracts the humidity of the air, and is soluble in less than its own weight of water. If this salt be exposed to heat in closed vessels, it suddenly explodes; part of the acid and alkali is destroyed; and the aërial product is phlogisticated air.

Production of nitrous acid.

If a mixture of two parts by measure of vital air, obtained without the use of nitrous acid, and one of phlogisticated air—or, which is the same thing, five parts of vital, and four of common air—be exposed to the action of the electric spark in the upper part of a syphon, in which it may be confined by mercury; and a small quantity of soap lees, or solution of pure vegetable alkali, be admitted into the cavity which contains the air; an absorption will take place, and nitrous acid will be produced, as appears by the alkali being converted into true nitre. This is a slow operation, and requires the quantity of air in the syphon to be renewed very often, to supply the absorption*. It has likewise been found that this acid is produced by exposing vital air for a long time to the exhalations of putrefying animal substances, together with calcareous earth, or any other proper base to receive and combine with it †. There can be little doubt

Nitrous acid produced; by Mr. Cavendish:

—by M. Thouvenel.

* For the detail of the particulars of this most curious experiment, consult Mr. Cavendish's papers, in the Phil. Transf. vol. lxxv. p. 372; and vol. lxxviii. p. 255.

† This is the discovery of M. Thouvenel. See his Prize Dissertation on the Formation of Nitre.

doubt but the putrid exhalations confifted chiefly of phlogifticated air. It appears therefore that this fubftance bears the fame relation to the nitrous acid as fulphur does to the vitriolic. As fulphur by combuftion, in which vital air is an indifpenfable requifite, becomes converted into vitriolic acid, fo phlogifticated air becomes converted into nitrous acid; though, on account of its being lefs combuftible, the red heat cannot be produced and kept up without the co-operation of electricity: and as fulphur, when in contact with the pure air of the atmofphere, and with a bafe proper for combining with the vitriolic acid, is converted into that acid by a flow combuftion in the pyrites; fo the like expofure of phlogifticated air, in contact with calcareous earth, to vital air, produces nitrous acid, though much more flowly, becaufe the bafe is lefs combuftible.

NITROUS ACID.

Inference.

It has already been mentioned that volatile alkali is a compound of phlogifticated and inflammable air.—Hence in feveral metallic folutions, wherein inflammable air might elfe have been extricated, a production of volatile alkali has been obferved to take place. This is naturally accounted for by the combination of the inflammable air with the phlogifticated air of the nitrous acid, while the other component part of the acid, namely the vital air, is employed in calcining the metal. The Rev. Ifaac Milner firft thought of inverting this procefs, and his attempts were crowned with the happieft fuccefs. He concluded, that if by any effect of the chemical affinities vital air could be made to engage with the phlogifticated air of volatile alkali, at the fame time that the other principle, namely the inflam-

Nitrous acid compofed by Mr. Milner.

NITROUS ACID.

inflammable air, should be either retained or disengaged, the result of such first combination would be the nitrous acid in some of its modifications.

For this purpose, he crammed a gun barrel full of manganese in coarse powder, which substance is known to obtain vital air by heat; and to one end of this tube be applied a retort containing the caustic volatile alkali.

Heat was then applied to the gun barrel; and, as soon as it was ignited, he placed a candle beneath the retort, which caused the volatile alkali to boil, and pass through the gun barrel in the form of alkaline air: the consequence was, that nitrous air was emitted at the other end of the tube.

He likewise repeated the experiment with success, using martial vitriol calcined to whiteness, instead of manganese*.

Nitrous acid with combustible matter.

The nitrous acid acts with peculiar energy on combustible substances, which it burns or calcines; and during most of these processes a peculiar kind of air flies off, which is called nitrous air. It is produced by the solution of many of the metals, by most vegetable, and some animal substances. This aërial fluid is not rapidly imbibed by water, and may therefore for temporary use be received over it. It is not heavier than common air; and possesses the remarkable property of suddenly uniting with vital air, with which it forms nitrous acid. The mixture of these two kinds of air forms a red cloud, which is imbibed by

Nitrous air,

* Mr. Milner's experiments are inserted in the lxxixth vol. of the Phil. Transf. The whole paper is highly deserving the attention of chemists.

the

NITROUS ACID.

the water, and renders it acid, if the experiment be performed over that fluid; and, from examination of this acid water, it is proved that the cloud is the nitrous acid itfelf. From this circumftance Dr. Prieftley inftituted a method of determining the purity or refpirability of the air of the atmofphere, or any other permanently elaftic fluid. He found, by a variety of experiments, that when nitrous air and any other air are mixed, they undergo no change, if the latter be totally unfit to fupport combuftion or animal life; but, if the contrary, the red cloud is formed; and the whole bulk of the mixture is diminifhed by a quantity which is fo much the greater, accordingly as the air in queftion is of a quality more fuited to thofe purpofes. This diminution he likewife proved to confift of a proportional part of the air which is tried, together with as much of the nitrous air as is required to produce the effect; fo that, if the nitrous air be duly proportioned to the effect, it will wholly difappear.

Dr. Prieftley's method of afcertaining the refpirability of air.

The trial of the purity of common air by means of nitrous air, has not however been found to exhibit fuch remarkable differences between the air taken up at various places as their known falubrity or unhealthinefs might have given reafon to expect. Two reafons may be offered to account for this. The firft is, that a fmall difference in the purity of the air of a place may have a very confiderable effect on the health of thofe who are obliged to breathe it for a long fucceffion of time: the fecond is, that, the effects of nitrous air being the fame upon elaftic fluids which contain equal proportions of vital air, however greatly their other component parts may differ in their pro-

Imperfections of the trial air by nitrous air.

 perties,

NITROUS ACID.

perties, it will only be ſhewn that the airs are equally ſalubrious, as far as depends on their proportion of vital air, though they may by no means be ſo with regard to their noxious parts.

Eudiometers.

There are ſeveral ingenious contrivances, called eudiometers, for the mixing of nitrous and other air, and meaſuring their diminution. As theſe however are not eaſily procured, and more eſpecially as Dr. Prieſtley, whoſe experience is greater than that of any other philoſopher, uſes a ſimple tube, it does not ſeem neceſſary to deſcribe them here. The doctor's method is as follows:

Dr. Prieſtley's method of aſcertaining the purity of air:

He firſt provides * a phial containing about an ounce of water, which he calls the air meaſure. This he fills with air, by having firſt filled it with water, and placed it over the opening of the funnel, in his ſhelf (fig. 15); and when it is filled, he ſlides it along the ſhelf, always obſerving that there be a little more air than is wanted. The phial being thus exactly filled with the air he is about to examine, and care being taken that it be not warmed by holding in the hand, he empties it into a jar of about an inch and a half in diameter; and then introduces to it the ſame meaſure of nitrous air, and lets them continue together about two minutes. The Doctor chooſes to have an overplus of nitrous air, that he may be ſure that its effect may be the utmoſt poſſible. If he finds the diminution of theſe two meaſures to be very conſiderable, he introduces another meaſure of nitrous air; but the pureſt vital air will not, he believes, require more than two meaſures of nitrous air.

* Prieſtley, iv. p. 30. I give the account nearly in his words.

Some-

NITROUS ACID.

Sometimes he leaves the common and nitrous air in the jar all night, or a whole day; but he always takes care, whenever he compares two kinds of air, that both ſhall remain the ſame length of time in the veſſels, before he notes the degree of diminution.

When the preceding part of the proceſs is over, he transfers the air into a glaſs tube, about three feet long, and one third of an inch wide, carefully graduated according to the air meaſure, and divided into tenth and hundredth parts; ſo that one of the hundredth parts will be about a ſixth or an eighth of an inch. Then immerſing the tube in a trough of water, ſo that the water in the inſide of the tube ſhall be on a level with the water on the outſide, he obſerves the ſpace occupied by the aërial mixture; and expreſſes the reſult in meaſures and decimal parts of a meaſure, according to the graduation of the tube.

Eudiometer tube.

It is ſome trouble to graduate a tube in this manner; but when it is once done, the application of it is extremely eaſy. As it ſeldom happens that a glaſs tube is of an equal diameter throughout, the Doctor generally fills that part of the tube which contains one meaſure with quickſilver; and then weighing it and dividing it into ten parts, he puts them in ſeparately, in order to mark the primary diviſions. The weighing is rendered very eaſy by the help of a glaſs tube, drawn to a fine orifice, which ſerves to take up a ſmall quantity at a time, as may be required in making the adjuſtment.

It has been already obſerved that common air loſes about one fourth of its bulk by any proceſs equivalent

NITROUS ACID.

to combuftion. This alfo happens when it is mixed with nitrous air.

Action of nitrous acid on animal fubftances.

When the nitrous acid acts upon the flefh, or other parts of animal fubftances, the elaftic fluid which is firft and moft plentifully difengaged is phlogifticated air. In this experiment the phlogifticated air may come from the animal fubftance, or the acid, or both; fince both contain it. It appears however to be much more probable that the whole comes from the animal fubftances; for it is afforded by the application of a very weak nitrous acid, at fo low a temperature as 65° or 70°; both which circumftances do not appear to indicate a decompofition of the acid. The nitrous acid, after its action, faturates as large a quantity of alkali as before*. The quantity of phlogifticated air is in proportion to the quantity of volatile alkali which the animal fubftance made ufe of affords by diftillation: and it is known that the quantity of phlogifticated air contained in any animal fubftance muft be in this proportion. And laftly, at a greater heat, after the phlogifticated air has come over, there is a difengagement of nitrous air, which indicates a lefs complete decompofition of the acid than that which would have afforded phlogifticated air: and it is not confonant with other chemical facts, that the complete decompofition of the

* The quantity of alkali faturated by an acid being different according to the ftate of the acid, with regard to what is called phlogiftication, this proof cannot be admitted as abfolutely conclufive, unlefs the fame quantity of true nitre be formed in both cafes. I do not find whether this has or has not been done. See Annales de Chimie, i. 42.

acid

acid ſhould happen at a lower heat than the partial decompoſition which ſucceeds it.

NITROUS ACID.

Various fluids imbibe nitrous air.

Water will imbibe about one tenth of its bulk of nitrous air, which, if immediately expelled by heat, is not found to be changed in its properties. The reſiduum which is not imbibed is phlogiſticated air. The vitriolic acid abſords nitrous air, and aſſumes a purple colour. The marine acid imbibes it, and becomes blue. Ether, alkaline liquors, and ſpirit of wine, alſo abſorb it.

Diminution of nitrous air by electricity, &c.

The electric ſpark diminiſhes nitrous air about one half, and converts it into phlogiſticated air, at the ſame time that acid is depoſited. Iron filings and brimſtone, liver of ſulphur, or iron alone, being expoſed to nitrous air, diminiſh it, and convert it into phlogiſticated air. But the moſt ſingular circumſtance in theſe proceſſes is, that, though they are of the nature of combuſtion, and do in the end render air perfectly unfit for maintaining it, yet, at a certain period before this, the air is put into a ſtate in which a candle burns in it better than in common air, though it ſtill continues perfectly deſtructive of animal life. Dr. Prieſtley calls this dephlogiſticated nitrous air.

Dephlogiſticated nitrous air.

Abſorption of nitrous air by the nitrous acid.

If nitrous acid be expoſed to nitrous air, the latter is abſorbed in large quantities; and the colour of the acid changes firſt at the ſurface, and gradually through the whole of the liquid: the ſucceſſions of colour are firſt yellow, then deep orange, next green, and laſtly blue, according to the quantities of nitrous air abſorbed. This abſorption renders the acid much more volatile. Hence it appears that the various colours of nitrous acid are owing to its having abſorbed nitrous air, which

NITROUS ACID.

which continually efcaping, and combining with the vital air of the atmofphere, forms the yellow or reddifh fumes it ufually emits when in an open veffel.

Pale nitrous acid, becomes yellow:

The pale or dephlogifticated nitrous acid, if expofed to the action of light, gives out pure air, and itfelf becomes yellow and fuming. Heat alfo produces the fame effect. The nitrous acid itfelf appears to be capable of fubfifting in the aërial form, though its power of combining with water, mercury, or any other fluid ufed for confining it, prevents experiments from being made upon it with the fame facility as with other kinds of air. Water impregnated with this air or vapour becomes fucceffively blue, green, and at laft yellow, when it has received an increafe of one third of its bulk. This water emits a great quantity of nitrous air, and does not feem to differ effentially from pure nitrous acid which has imbibed nitrous air.

—is capable of the elaftic form.

Inflammation of effential oils by nitrous acid:

One of the earlieft known facts of fpontaneous inflammation is that produced by the affufion of the nitrous acid upon oil. All the oils obtained by diftillation from vegetables, and known by the name of effential oils, are proper for this experiment. An ounce of the oil intended to be fet on fire muft be placed in a fhallow veffel, and a bottle containing an ounce of the moft concentrated nitrous acid muft be faftened at the end of a pole, that the operator may be fufficiently diftant from the inflammation. Two thirds of the acid being poured on the oil, makes a confiderable ebullition; the oil growing black and thick, and fometimes taking fire. But if this laft circumftance does not happen in five or fix feconds, the remainder of the acid muft be poured where the mixture appears moft dry and

NITROUS ACID.

and black; and then the inflammation feldom fails to take place.

—of fat oils:

Fat oils may alfo be inflamed, if equal parts of the nitrous and vitriolic acids be firft poured on them, and, when the ebullition is at the greateft, a portion of nitrous acid be poured on the drieft part.

—of charcoal, or lamp black.

Strong nitrous acid, of the fpecific gravity of 1.54, being added to the powder of charcoal, or lamp black*, recently made very dry, takes fire, and detonates. There is fome uncertainty in this experiment; but the method which is faid to enfure fuccefs, is, to put the dry powder into a very dry retort, and pour the acid upon the fide of the glafs, fo that it may not fall upon the powder, but flow beneath it.

The production of heat in thefe phenomena, which doubtlefs arifes from the action exerted between the combuftible body and the vital air of the acid, has not yet been explained in an adequate manner from experiments tending to fhew how the capacities of the bodies are changed by the procefs.

Recapitulation and theory.

On a review of the facts in the foregoing chapter, it will not be difficult to apply in a general way the fame theories as were exhibited in treating of the vitriolic acid. The preparation of nitre beds confifts fimply in a procefs by which the exhalations of putrid fubftances may combine with vital air, and the product be received into a combination with calcareous earth, or with the alkali of decayed vegetables; and the fubfequent manipulations are the mere application of water, to feparate the feveral matters from each other according

* Prouft in the Journal de Medecine, for July 1778.

NITROUS ACID.

to their refpective degrees of folubility. That nitrous acid contains vital air, is evident from the diftillation of nitre without addition; and that in the acid it is applied to, or combined with, phlogifticated air, appears equally clear from the * experiment of Mr. Cavendifh, and from the frequent appearance of this aërial fubftance in experiments with nitrous air. The queftion in this procefs therefore feems to be, whether the air called phlogifticated air do really contain an inflammable principle, which it gives out during combination with the vital air; or whether it fimply unite to this laft? Upon the former fuppofition, the theory of the general facts will be as follows:

Theory.

Nitrous acid confifts of vital air united to a certain proportion of phlogifticated air, which has been deprived of phlogifton during combination. When a combuftible body is prefented to this acid, it becomes corroded or burned; that is to fay, it combines with fome of the vital air, and parts with fome of its own phlogifton. In this ftate the acid is no longer the fame; for it has loft vital air, and part of its phlogifticated air has regained phlogifton. It therefore emits either nitrous air, which is an imperfect nitrous acid, wherein the phlogifton is too abundant, and the vital air too deficient, to exhibit acid properties; which on that account readily abforbs vital air, and is by that means precipitated again in the original acid form: or, if the decompofition be more completely made, the quantity of vital air abforbed, and of phlogifton emitted, by the combuftible body, may be fuch as that only phlogifticated air fhall be extricated, as is the cafe with

Page 164.

Page 167.

* Phil. Tranf. quoted, page 152.

animal

animal fubftances. Again, the compofition of nitrous air being thus eftablifhed, if the electric fpark be applied to produce ignition in this aërial fluid, the fmall portion of vital air intimately unites with as much of the phlogifticated air as is required to form nitrous acid, and leaves the refidue of phlogifticated air behind: or, if any procefs of flow combuftion be carried on in it, the whole of the vital air is abforbed, and as much phlogifton extricated as converts the refidue into phlogifticated air. It is evident that the abforption of nitrous air muft equally alter the proportions of the component parts of the nitrous acid, and produce fimilar effects.

Page 169.

Ibid.

Ibid.

The fingular properties of the air called dephlogifticated nitrous air have not been fatisfactorily explained upon any theory.

Theory: —of the antiphlogiftians.

It is obvious that the explanation of thefe events may be made at leaft with equal facility according to the other theory. Phlogifticated air and vital air are applied to each other under certain circumftances, and nitrous acid is produced. Hence it is concluded that thefe aërial fubftances have united together, and are the component parts of nitrous acid. When an inflammable fubftance is burned, or a metal calcined, by the action of this acid, one of its component parts, namely, vital air, unites with the body; and the furplus of the other principle, namely, phlogifticated air, flies off either alone, or in combination with a fufficient portion of vital air to form nitrous air. The addition of vital air to this laft aërial product completely forms nitrous acid; the fubtraction of the vital air it poffeffes muft change it into phlogifticated air.

The

NITROUS ACID.

Action of light.

The phenomenon of nitrous acid becoming yellow and fuming by the action of light or heat, will ſhew that it receives phlogiſton, according to the ancient hypotheſis. As it ſeems however to be a bold ſuppoſition, that either light or heat, conſidered as matter, can transfer the inflammable principle through glaſs veſſels, the fact has been more ingeniouſly explained by recourſe to the decompoſition of water. It is aſſerted that the nitrous acid attracts the inflammable air, or phlogiſton, of the water, and ſets its vital air at liberty.

Theory.

According to the antiphlogiſtic theory, it is ſimply ſaid that heat or light expels part of the vital air from the nitrous acid, as the event ſhews; and that the reſidue, having an over-proportion of phlogiſticated air, is of courſe coloured and fuming.

The reader may eaſily apply theſe theories to the combuſtion of oils or charcoal by the nitrous acid, as far as the facts can be clearly ſtated, or are known: for theſe are doubtleſs of the ſame nature as other combuſtions.

Keir's compound acid. See chap. ii. book ii.

It is a late diſcovery of Mr. Keir*, that a mixture of the concentrated vitriolic and nitrous acids forms a ſolvent peculiarly calculated to diſſolve ſilver in a large proportion; though it has ſcarcely any efficacy in ſuſpending any other metallic ſubſtance. He forms it by diſſolving nitre in concentrated vitriolic acid. Tin, mercury, and nickel, are acted upon, and chiefly calcined, by this compound acid; the latter being diſſolved in a ſmall quantity: but it has little or no action upon the other metals. Dilution with water renders it leſs capable of diſſolving ſilver, but more active with regard to the other metals.

* Phil. Tranſ. vol. lxxx. p. 373.

If

NITROUS ACID.

If this acid be digeſted upon ſulphur, it undergoes the change called phlogiſtication, and emits nitrous fumes; the nitrous acid probably loſing its acidity in proportion as the ſulphur becomes acidified. Its affinities, or ſolvent powers, are conſiderably changed by this proceſs. The ſame phlogiſticated acid is afforded, if the nitrous vapour or air be added to vitriolic acid, inſtead of common nitre; or if nitre with baſis of volatile alkali be uſed.

CHAP. III.

OF THE MARINE ACID AND ITS COMBINATIONS, INCLUDING AQUA REGIA.

COMMON SALT.

Salt mines and springs.

Sea water.

THE marine acid is obtained from common culinary falt, in which it is united to the mineral alkali. Common falt is found in large maffes, or in rocks, under the earth, in England and elfewhere. There are alfo many falt fprings in various parts of the world; and the waters of the ocean every where abound with it, though in different proportions. The water of the Baltic fea * is faid to contain one fixty-fourth of its weight of falt; that of the fea between England and Flanders contains one thirty-fecond part; that on the coafts of Spain one fixteenth part; and between the tropics it is faid, perhaps erroneoufly, to contain from one eleventh to one eighth part.

Extraction of common falt from waters.

The whole art of extracting falt from waters which contain it, confifts in evaporating the water in the cheapeft and moft convenient manner. In England, a brine compofed of fea water, with the addition of rock falt, is evaporated in large fhallow iron boilers; and the cryftals of falt are taken out in bafkets. In Ruffia, and probably in other northern countries, the fea water is expofed to freeze; and the ice, which is almoft entirely frefh, being taken out, the remaining brine is much ftronger, and is evaporated by boiling.

* Romé de l'Ifle's Cryftallographie, vol. i. p. 375, quoted by Magellan in his improved edition of Cronftedt, p. 360.

In

COMMON SALT.

In the fouthern parts of Europe the falt-makers take advantage of fpontaneous evaporation. A flat piece of ground near the fea is chofen, and banked round, to prevent its being overflowed at high water. The fpace within the banks is divided by low walls into feveral compartments, which fucceffively communicate with each other. At flood tide, the firft of thefe is filled with fea water; which, by remaining a certain time, depofits its impurities, and lofes part of its aqueous fluid. The refidue is then fuffered to run into the next compartment; and the former is again filled as before. From the fecond compartment, after a due time, the water is transferred into a third, which is lined with clay, well rammed, and levelled. At this period the evaporation is ufually brought to that degree, that a cruft of falt is formed on the furface of the water, which the workmen break, and it immediately falls to the bottom. They continue to do this until the quantity is fufficient to be raked out, and dried in heaps. This is called bay falt.

Various methods —of obtaining falt: —from the waters

In fome parts of France, and alfo on the coafts of China, they wafh the dried fands of the fea with a fmall proportion of water, and evaporate this brine in leaden boilers.

—of the fea

At feveral places in Germany, and at Montmarot in France, the waters of falt fprings are pumped up to a large refervoir at the top of a building or fhed; from which it drops or trickles through fmall apertures upon boards covered with brufh wood. The large furface of the water thus expofed to the air, caufes a very confiderable evaporation; and the brine is afterwards con-

—and falt fprings.

N veyed

COMMON SALT.

veyed to the boilers for the perfect feparation of the falt.

Salts contained in the fea.

The water of the fea contains, befides the common falt, a confiderable proportion of magnefian marine falt, and fome gypfum, or lime combined with vitriolic acid. The magnefian falt is the chief ingredient of the remaining liquid which is left after the extraction of the common falt, and is called the mother water. Sea water, if taken up near the furface, contains alfo the putrid remains of animal fubftances, which render it naufeous, and in long continued calms caufe the fea to ftink.

Cryftallization of common falt.

The cryftals of common falt are right-angled fix-fided folids, and are ufually faid to be cubes. Thefe form at the furface, where the evaporation is the greateft; and they float by virtue of the repulfive power of their dry upper furfaces, which difplaces a quantity of the furrounding water: a circumftance common to all fuch fmall bodies as are not eafily wetted. When the cryftal becomes too large to be fufpended in this way, it finks. If two floating cryftals come fo near each other as that the hollow fpaces may communicate, they fall together into one cavity at the furface, without finking; and the fucceffive appofition of other cryftals often produces a curious hollow pyramid, which is fquare, becaufe the figure of the cryftals themfelves occafions them to apply to each other only in the pofition required to produce fuch a folid.

Common falt does not alter in the air; but when expofed to heat, it cracks and flies in pieces, by the

efcape

MARINE ACID.

escape of its water of cryſtallization. A greater heat ignites and melts it; and a ſtill greater cauſes it to riſe totally in white fumes. The action of ſea ſalt upon earths is not conſiderable. It aſſiſts the fuſion of ſiliceous earth; and is thrown into the furnace wherein the pottery called ſtone-ware is baked, where it riſes in fumes, and glazes their ſurface; probably by the combination of its alkali with the ſiliceous earth contained in the clay. The decompoſition of ſea ſalt by litharge has already been mentioned in treating of the mineral alkali. Page 122.

Diſtillation of marine acid from common ſalt.

The marine acid may be obtained from common ſalt by proceſſes ſimilar to thoſe deſcribed for procuring the nitrous acid in the preceding chapter. The moſt effectual and elegant way conſiſts in applying one part by weight of ſtrong vitriolic acid to three of decrepitated ſea ſalt, in a retort whoſe upper part is furniſhed with a tube or neck, through which the acid is to be poured upon the ſalt. The aperture of this tube muſt be immediately cloſed with a ground ſtopper after the pouring. The vitriolic acid immediately combines with the alkali, and expels the marine acid in the form of a peculiar air; which is rapidly abſorbed by water, but may be confined by mercury. As this combination and diſengagement take place without the application of heat, and the aërial fluid eſcapes very readily, it is neceſſary to arrange and lute the veſſels together before the vitriolic acid is added, and not to make any fire in the furnace until the diſengagement begins to ſlacken; at which time it muſt be very gradually raiſed. Before the modern improvements in chemiſtry were made, a great part of

Marine acid air:

MARINE ACID.

Diftillation.

the acid efcaped, for want of water to combine with; but by the ufe of the apparatus, fig. 21 or 22 (or a combination of veffels equivalent to both of them), the acid air is made to pafs through water, in which it is condenfed, and forms marine acid of double the weight of the water, though the bulk of this fluid is increafed one half only. The acid condenfed in the firft receiver, which contains no water, is of a yellow colour, arifing from the impurities of the falt.

Marine acid air:

Heat expels the marine acid air from marine acid, and leaves the water behind. The fumes of fpirit of falt confift of this air in the act of uniting with the watery vapours of the atmofphere, which render it vifible. This air has nearly the fame affinities as the acid itfelf in the fluid form. The electric explofion diminifhes it a little; but the remainder is almoft totally foluble in water as before.

its corrofive nature.

It is an object of confiderable importance to the practical chemift, to be aware of the corrofive nature of this acid air. If the proceffes in which it is fet at liberty be carried on in a room where balances and other metallic inftruments are kept, though the quantities may not be perceptible by the fmell or otherwife, yet the inftruments will in the courfe of a few days be covered with ruft. It is indeed by no means prudent to keep, or make ufe of, any delicate metallic inftruments in the fame apartment which is appropriated to chemical proceffes.

Salt of Sylvius.

The marine acid, in combination with the vegetable alkali, forms a falt called falt of Sylvius, or, improperly, regenerated fea falt. It is of a bitter tafte, flightly deliquefcent, and foluble in about three times its

its weight of water. This is fometimes ufed in medicine. MARINE ACID.

With the volatile alkali it forms common fal ammoniac, which is a confiftent falt, of a fharp briny tafte; and fo remarkably deficient in the ufual brittlenefs of this clafs of bodies, that it is not eafily pulverized. It is foluble in between three and four times its weight of water, in a common temperature. By heat it fublimes entire in clofed veffels. Sal ammoniac.

The faline combination of lime with marine acid is fometimes called marine felenite, and fometimes fixed ammoniac; becaufe it forms the fixed refidue after fal ammoniac has been expofed to diftillation with lime. This falt may be obtained in the form of cryftals, but it deliquefces with air. It is foluble in lefs than twice its weight of cold water. The combination of lime and marine acid which remains after diftilling fal ammoniac, has ufually an over-proportion of lime. If it be urged by a violent heat, it fufes; and when cold, it has the property of emitting a phofphoric light upon being ftruck with any hard body. Hence it is called Homberg's phofphorus, from the name of the firft obferver. Marine felenite. Homberg's phofphorus.

The argillaceous marine falt has a gelatinous confiftence when diffolved in a fmall quantity of water. Its tafte is ftyptic, and it affords cryftals by fpontaneous evaporation. Argillaceous marine falt.

The combination of ponderous earth with marine acid forms a cryftallizable falt of difficult folution. Its folution is of admirable ufe for detecting the prefence of the vitriolic acid in any fluid; becaufe this air combines with the earth, and forms an infoluble Ponderous marine falt.

 preci-

MARINE ACID.

precipitate of ponderous fpar. It is more efpecially ufeful for purifying the marine acid itfelf from the vitriolic acid, which it often contains. The exact quantity of folution neceffary to be added for this purpofe to any veffel of marine acid, may be known by previous trials with fmall portions of the acid.

Magnefian marine falt.

Magnefian marine falt exifts in all falt waters. It is foluble in lefs than its own weight of water; and cannot be obtained in the cryftalline form but by firft evaporating its folution, and then fuddenly expofing it to a great degree of cold. It is the caufe of the bitternefs of fea water: and, like moft of the other falts laft defcribed, it is applied to no ufeful purpofe.

Action of marine acid upon metals.

The marine acid has fcarcely any action upon combuftible fubftances in general. It acts directly upon tin, lead, copper, iron, zinc, bifmuth, antimony, manganefe, arfenic; but does not affect gold, filver, platina, mercury, wolfram, or cobalt.

Dephlogifticated or aerated marine acid.

If the marine acid be diftilled from about one fourth of its weight of the black calx of manganefe, a fuffocating elaftic fluid arifes, which corrodes mercury, and is abforbed by water. The impregnation of water with this fluid (which was named the dephlogifticated marine acid by its difcoverer SCHEELE) may be conveniently performed by means of the apparatus, fig. 21 *. If the concentrated marine acid be ufed, the difengagement takes place without heat; but if it be weaker, the application of a gentle heat is neceffary. The common marine acid which may rife is condenfed in the firft bottle; and the dephlogifticated acid unites to the

* Berthollet, in the Mem. Acad. Par. for 1785; and in Rozier's Journal for Sept. 1788.

MARINE ACID.

Dephlogifticated or aerated marine acid.

the water in the fecond; the water, as it becomes faturated, affumes a greenifh yellow colour. When the faturation is complete, the dephlogifticated acid takes a concrete form, and defcends to the bottom in yellowifh flocks, provided the temperature of the water be only a few degrees above freezing. An increafe of temperature, fuch as may be produced by applying the hand to the veffel, caufes this concrete matter to affume the aërial form, and efcape in bubbles to the furface. The tafte of the folution is auftere, but does not refemble that of acids. It combines with fixed alkalis without caufing them to give out their fixed air, if they be in a mild ftate. Heated with lime, or fixed alkali, it emits vital air, and then forms the fame faline combinations as the common marine acid would have done. It diffolves all metals directly, without affording inflammable air, as the marine acid does with fome of them; and its faline combinations are, for the moft part, the fame as the common acid produces when made to combine with thofe bodies. It deftroys vegetable colours, rendering them white without firft caufing them to become red; it bleaches wax; and in general produces immediately, in a variety of fubftances, the fame changes as are effected by long expofure to air. This property has already been applied with fuccefs in manufactories.

Annales de Chimie, ii. 151—190.

Salt into which dephlogifticated marine acid enters.

When the aëriform dephlogifticated marine acid is received in a folution of pure vegetable alkali, and the liquor evaporated, two kinds of falt are obtained. The one is the common falt of Sylvius, which feparates from the fluid as the evaporation goes on; and the other is a falt which, being more foluble in hot

MARINE ACID.

Detonating marine salt with base of vegetable alkali: than in cold water, affords cryſtals by cooling. Theſe are of a long rhomboidal figure, and a ſilvery brilliancy; have an inſipid cooling taſte, reſembling nitre; do not deliqueſce in the air; and detonate with charcoal, or with iron, more ſtrongly than nitre itſelf does. By heat alone they give out vital air; and the reſidue of their detonation with charcoal is the ſalt of Sylvius. Hence it is obvious, that a portion of the alkali has imbibed ſome of the dephlogiſticated marine acid, together with the overplus of vital air contained in a great part of the reſt of the acid; and that this alkali forms the preſent ſalt; while the acid which was deprived of the overplus, and by that means reduced to the common ſtate, forms the ſalt of Sylvius, which is in much the greateſt proportion in the ſolution.

—with mineral alkali: If the mineral alkali be uſed, a ſalt nearly of the ſame nature is formed; but too deliqueſcent to afford cryſtals.

—volatile alkali. Volatile alkali is decompoſed by the dephlogiſticated marine acid; the vital air combining with its inflammable part, and the phlogiſticated air flying off.

Action of light. When the ſolution of dephlogiſticated marine acid is expoſed to the action of light, it emits vital air, and becomes converted into common marine acid.

Theory. When we reaſon by analogy from the vitriolic and nitrous to the marine acids, we muſt conclude that this laſt conſiſts of a baſe of a combuſtible nature united to vital air. And as the greater combuſtibility of ſulphur, the baſe of the vitriolic acid, when compared with phlogiſticated air, or the baſe of nitrous acid, appears to be the cauſe why the action of the latter is more generally effectual upon combuſtible bodies,

bodies, to which it can with more facility transfer its vital air, and probably receive phlogifton from them at the fame time; fo the bafe of marine acid, being apparently lefs combuftible than even that of the nitrous, may, in its ordinary ftate of acidity, hold too fmall a quantity of vital air, or too large a proportion of phlogifton, to act with energy on other combuftible bodies. But whenever it is combined with a furplus of vital air from the calx of manganefe (which certainly contains it, becaufe it affords it by fimple heat), it muft act with great effect on bodies which are difpofed to combine with that principle, for the fame reafon as the nitrous acid does; namely, becaufe it is eafily decompofed. And this reafon will in fact be the fame, whether the action of acids be confidered according to the modern theory, as confifting chiefly in the combination of vital air with the combuftible body; or whether this laft be fuppofed in the old theory to afford phlogifton to the bafe, or other component part, of the acid.

Action on combuftible bodies.

It muft be confeffed however, that the general circumftances attending the change which the marine acid fuffers by the acceffion of vital air, are not ftrictly confonant throughout with what happens to the other acids. The phlogifticated vitriolic and nitrous acids are rendered more acid by the addition of vital air, which is generally admitted to be the chief principle of acidity. The marine acid, on the contrary, has its activity increafed, by fuch an addition or change, only with refpect to combuftible bodies; but is lefs active on the alkalis and earths, infomuch that fome writers have thought it might be denied to be an acid.

Acidity of marine acid does not vary after the law of other acids.

AQUA REGIA. Theory.

acid. From this inſtance acidity appears to have its limits, ſo as to conſiſt of a preciſe term of dephlogiſtication, or of ſaturation with vital air; and to be impaired or deſtroyed by an exceſs either way. A full and adequate explanation of the changes of the marine acid cannot but afford much advantage to the general theory of acids, which occupy ſo large a ſpace among the objects of chemical inquiry.

Compoſition of aqua regia:

When one or two parts of pale concentrated nitrous acid are mixed with four parts of fuming marine acid, an effervefcence ſoon takes place *, and dephlogiſticated marine acid flies off in the aërial form, at the ſame time that the mixture becomes of a deep red colour. The mixed acid is called aqua regia; and has been long remarkable for its property of diſſolving gold, which is not ſenſibly acted upon by either of the acids that compoſe it.

—otherwiſe.

Aqua regia may be made by adding to nitrous acid any ſalt which contains the marine acid: for the affinity of the nitrous acid to the baſe being in moſt caſes ſtronger than that of the marine, this laſt is ſet at liberty; and conſequently the mixture, if the ſalt be not exceſſive in quantity, will contain the acids in a diſengaged ſtate. An aqua regia will therefore be produced, which is not eſſentially impaired with reſpect to common uſes by the portion of ſalt it may hold in ſolution. It is uſual to make aqua regia by diſſolving ſal ammoniac in about four times its weight of ſtrong nitrous acid; but the reſults

* Berthollet, in Acad. Par. 1785.

of

of experiments or operations muft vary confiderably according to the proportion and the ingredients made ufe of.

The effects and theory of aqua regia.

The nature of this mixed acid has not yet been clearly afcertained. After the difcovery of the dephlogifticated marine acid, it was concluded, that the nitrous acid performed the fame office as the manganefe does; that is, in fact, that it either deprives the marine acid of phlogifton, or affords vital air to combine with it, or both. Several difficulties however oppofe this fuppofition. If the marine acid be enabled to calcine and diffolve gold becaufe it has been dephlogifticated or aërated by the nitrous acid, it fhould follow much more ftrongly that the nitrous acid itfelf fhould diffolve that metal, which is contrary to the fact. And, again, it has not been fhewn how this dephlogifticated acid, which is fo volatile, and fo fparingly foluble in water, is retained in the folution: not to mention that no component part of the nitrous acid is found to efcape during the effervefcence, except the vital air which enters into the compofition of the gas that flies off. When the two acids are in due proportion, therefore, aqua regia muft confift of marine acid, and nitrous acid which has an under-proportion of vital air, or is in the moft fuming ftate; or, in other words, it contains the two bafes of the acids, together with vital air, lefs in quantity than they poffeffed in their feparated ftate. But, whether thefe principles combine and form a compound acid, or in what other order they may be arranged, has not yet been experimentally determined; though the writings of chemifts abound with conjectural inferences refpecting them.

The

AQUA REGIA.

Combinations.

The combinations of earths and alkalis, and even of metals, with aqua regia, have not been well examined. It is not known whether two different kinds of falts are formed apart from each other, or whether a triple combination takes place confifting of two acids united to one bafe. It appears however that in fome cafes the refult is one entire compound, and in others two feparate ones.

CHAP.

CHAP. IV.

OF FIXED AIR, FIXABLE AIR, OR AERIAL ACID.

FIXED AIR.

THE acid which is commonly known by the name of fixed air, abounds in great quantities in nature, and appears to be produced in a variety of circumftances. It compofes about one third of the weight of limeftone, marble, calcareous fpar, and other natural fpecimens of calcareous earth, from which it may be extricated either by the fimple application of heat, or by the fuperior affinity of fome other acid; moft acids having a ftronger action on bodies than this. This laft procefs has been before defcribed. It does not require heat, becaufe fixed air is ftrongly difpofed to affume the elaftic ftate. Water, under the common preffure of the atmofphere, and at a low temperature, abforbs fomewhat more than its bulk of fixed air, and then conftitutes a weak acid. If the preffure be greater, the abforption is augmented. Heated water abforbs lefs; and if water impregnated with this acid be expofed on a brifk fire, the rapid efcape of the aërial bubbles affords the appearance of the water being at the point of boiling, when the heat is not greater than the hand can bear. Congelation feparates it readily and completely from water; but no degree of cold or preffure has yet exhibited this acid in a denfe or concentrated ftate of fluidity.

Subftances which contain fixed air.

Page 52—55.

Impregnation of water.

Fixed air is nearly twice as heavy as common air; and for that reafon occupies the lower parts of fuch mines

FIXED AIR.

mines or caverns as contain materials which afford it by decompofition. The miners call it choke damp.

Groto del Cano.

The Groto del Cano, in the kingdom of Naples, has been famous for ages on account of the effects of a ftratum of fixed air which covers its bottom. It is a cave or hole in the fide of a mountain near the lake Agnano, meafuring not more than eighteen feet from its entrance to the inner extremity; where if a dog, or other animal that holds down its head, be thruft, it is immediately killed by inhaling this noxious fluid.

Fixed air emitted from fermenting bodies.

Fixed air is emitted in large quantities by bodies in the ftate of the vinous fermentation; and on account of its great weight it does not fly off, but remains in the upper fpace of the veffel, not occupied by the fermenting body. A variety of ftriking experiments may be made in this ftratum of elaftic fluid. Lighted paper or a candle dipped into it, is immediately extinguifhed; and the fmoke remaining in the fixed air renders its furface vifible, which may be thrown into waves by agitation, like water. If a difh of water be immerfed in this air, and brifkly agitated, it foon becomes impregnated, and obtains the lively tafte of Pyrmont water. In confequence of the weight of the fixed air, it may be dipped out in a pitcher, or bottle; which, if well corked, may be ufed to convey it to great diftances. The effects produced by pouring this invifible fluid from one veffel to another, have a very fingular appearance: if a candle, or a fmall animal, be placed in a deep veffel, the former becomes extinct, and the latter expires, in a few feconds after the fixed air is poured upon them, though the eye is incapable of diftinguifhing any thing that is poured.

Experiments made in an atmofphere of fixed air.

4 When

FIXED AIR.

When vegetable fubftances are expofed to a ftrong heat in veffels partly clofed, the volatile principles fly off; but combuftion does not take place for want of air. The fixed refidue is the inflammable fubftance called charcoal. For general purpofes, wood is converted into charcoal by building it up in a pyramidical form, and covering the pile with clay or earth, leaving a few air-holes, which are clofed when the mafs is perfectly lighted; and by that means the combuftion is carried on in an imperfect manner. Common charcoal, when expofed to heat in clofed veffels, gives out a fmall quantity of inflammable air, which feems extraneous to it; and if it be burned, it leaves a fmall portion of earth, fixed alkali, and other falts. The greater part of charcoal therefore confifts of an inflammable fubftance; and it is found that, if this be burned in a clofed veffel over mercury, with vital air, the product is fixed air, and nothing elfe; as is proved by the refidue after the fixed air has been abforbed by cauftic fixed alkali: for there is either no aërial refidue, or the refidue confifts of vital air as pure as at firft*.

Converfion of vegetable matter into charcoal.

Production of fixed air from charcoal.

Hence it follows, that fixed air confifts of the inflammable matter of charcoal united to vital air. The antiphlogiftian philofophers confider this matter as a peculiar combuftible and acidifiable bafe, and thence infer the prefence of charcoal in all cafes where fixed air is extricated or produced: but, on the other hand, feveral of the phlogiftians think themfelves juftifiable in concluding that fixed air is produced by the union

Compofition of fixed air.

Opinions.

* Lavoifier in Mem. Acad. Par. for 1781, p. 449.

of

FIXED AIR. of inflammable air with vital air, when either of them is in the nafcent ftate, or ftate of extrication.

The electric fpark paffed through fixed air.

When the electric fpark * is paffed through fixed air confined by mercury, the volume of air is augmented about one twenty-fourth part; and of this three fifths are abforbed by a folution of cauftic alkali, and the remainder is inflammable. An eminent philofopher of the phlogiftic opinion fuppofes this effect to arife from the decompofition of the fixed air, whofe vital air, combining more intimately with part of the inflammable air, forms water, the refidue of this laft air being difengaged. But the chemift who made the experiment accounts for it as follows, without fuppofing the fixed air to be decompofed :—The air of the atmofphere, and other elaftic fluids, are proved by experiment to be capable of retaining mercury in folution; fo likewife in all probability does the fixed air: and they all retain much water. Whenever therefore the electric fpark, by paffing through this mixture of fixed air, mercury, and water, ignites a minute portion of it, the vital air of the water unites with and calcines the mercury; while the inflammable air of the water is fet at liberty; and the fixed air, like other acids, unites to the mercurial calx, and falls down with it. He fuppofes, from analogy, that the water in the fixed air increafes its volume by rarefying it; and that the fubtraction of the water occafions a contraction, while

Phlogiftic explanation.

Antiphlogiftic explanation.

* This experiment, firft performed by Prieftley, i. 248, has fince been repeated by Van Marum and others. The experiment of M. Monge, quoted by Kirwan in his Effay on Phlogifton, p. 193; fecond edition, is that fpoken of in the text: and the opinions are thofe of Meff. Kirwan and Monge.

the difengagement of the inflammable air produces a fomewhat greater augmentation of bulk. In this way (fuppofing the water and mercury to be prefent in fufficient quantity) the whole of the fixed air may enter into a folid combination, and nothing remain but inflammable air. Additional experiments muft however be made, before either opinion can be eftablifhed.

Combinations of fixed air; with clay:

Fixed air does not appear to be ftrongly difpofed to unite with argillaceous earth. Moft clays however afford a fmall quantity of this fluid by heat; and the fnowy white fubftance refembling chalk, and known by the name of lac lunæ, is found to confift of clay faturated with fixed air. A faline fubftance, confifting of two fix-fided pyramids joined at one common bafe, weighing five or fix grains, and of a tafte fomewhat refembling alum, was produced by leaving an ounce phial of water, impregnated with fixed air and a redundancy of earth of alum, expofed to fpontaneous evaporation for fome months.

—with calcareous earth:

Calcareous earth and fixed air have a ftrong attraction for each other. Moft of the fpecimens of calcareous earth abound with this acid; and the immediate precipitation of lime from lime-water is the teft of the prefence of this acid.

—with ponderous earth:

Ponderous earth combines very ftrongly with fixed air. This compound has been found in England; and, like the foregoing, has already been treated of in the chapter on earths.

—with magnefia.

Magnefia unites readily to a large proportion of fixed air.

Page 106.

The ufual method of procuring magnefia is, by precipitation from a folution of Epfom falt, by adding

FIXED AIR.

Cryftallized combination of magnefia with fixed air.

an alkali which combines with the acid. When a mild fixed alkali is ufed, it is neceffary that the faline folutions fhould be boiling hot, and the ebullition continued for a fhort time, in order to diffipate a portion of fixed air, which would hold part of the magnefia in folution. From this caufe it is, that perfectly mild vegetable alkali affords no precipitate when added to a folution * of Epfom falt at the temperature of 60°. The mineral alkali, which contains lefs fixed air than the cryftallized vegetable alkali, likewife affords but a fmall quantity of precipitate, unlefs heat be applied. Mild volatile alkali alfo poffeffes the property of affording no precipitate when added to a folution of Epfom falt in the cold: with a greater heat magnefia is feparated; and at a boiling heat it is again taken up, moft probably forming a triple falt compofed of vitriolic acid united to volatile alkali and magnefia. The faline combination of magnefia and fixed air is feparated in cryftals from all thefe cold folutions by ftanding uncovered; during which time the fixed air, which held the magnefia in folution, is no doubt gradually diffipated. The cryftals afforded when vegetable alkali is ufed, are contaminated with vitriolated tartar, which feparates at the fame time; thofe obtained by mineral alkali are finer and purer: but the moft beautiful and pureft are obtained by leaving the folution to which volatile alkali has been added, expofed for fome days in an oblong veffel.

* One part Epfom falt, diffolved in fix parts water, was mixed with one part cryftallized vegetable alkali, diffolved in five parts water. Confult Fourcroy in the Annales de Chimie, ii. 282, from whom the whole of this article refpecting aerated magnefia is taken.

Combinations of fixed air:

This cryſtallized aërated magneſia has uſually the form of ſix-ſided priſms. It is almoſt taſteleſs; effloreſces in the air; becomes pulverulent by heat, by the loſs of its fixed air and water; is ſoluble in about forty times its weight of water at the temperature of 55°. Half its weight conſiſts of fixed air, one fourth water, and one fourth magneſia; whereas the common aerated magneſia obtained by rapid precipitation contains forty parts magneſia, forty-eight fixed air, and twelve water.

—with earths:

All the earthy combinations of fixed air are nearly inſoluble in water; they are all more ſoluble with an exceſs of that acid than in mere water; and they all give out their fixed air by heat, except the native ſpecimen of aërated ponderous earth. The laſt contains no water; and water ſeems to be eſſentially neceſſary to enable bodies to aſſume the aërial form.

Fixed air has no action upon ſiliceous earth.

—and with alkalis:

The three alkalis form concrete cryſtallizable ſalts when united with fixed air, which being in fact neutral ſalts, are much leſs active than the cauſtic or pure alkalis themſelves. Theſe ſalts ſtill continue to be called the mild alkalis; becauſe the fixed air, though it forms a large proportion of their weight, is diſplaced by moſt other acids, and therefore does not obviouſly ſeem to impair their alkaline properties: beſides which, as this volatile acid flies off in the elaſtic form, and is loſt in common experiments (exhibiting no other indication of its preſence than the violent ebullition which accompanies its eſcape), it was formerly overlooked, and even at the preſent time is not always ſufficiently attended to.

FIXED AIR.

Alkaline air and fixed air unite, and form the concrete volatile alkali.

Combination of fixed air with combuftible matter.

The combinations of fixed air with inflammable fubftances have not been accurately examined. Metallic calces ufually contain more or lefs of this acid. Plumbago, or black lead, is the moft remarkable compound into which it enters. This affords much fixed air: but chemifts are not agreed with refpect to its combuftible part; fome confidering it as the mere principle of inflammability, and others afferting it to be iron.

Advantages derived from a knowledge of this acid.

When we take a retrofpective view of the numerous difficulties in chemical fcience refpecting the mild and cauftic ftate of lime and alkalis, and their effervefcence with acids in the one but not the other ftate; the interrupted effects of affinities; the pernicious effects of caverns, or of places where charcoal is burned, or proceffes of fermentation are carried on; the nature of medicinal fprings, and the component parts of a large proportion of mineral as well as organized bodies, which embarraffed the world before the difcovery of this acid; we have juft reafon to affirm that the name of Dr. Black of Edinburgh would have been immortal, if this had been the only one of the many difcoveries which he has added to the mafs of human knowledge.

CHAP.

CHAP. V.

OF THE ACID OF BORAX.

BORAX.

BORAX is a falt which comes to us from the Eaft Indies, and whofe origin has till lately been very dubious. At prefent however it is very well afcertained * that it is dug up in a cryftallized ftate from the bottom of certain falt lakes in a mountainous, barren, volcanic diftrict, about five-and-twenty days journey to the eaftward of Laffa, the capital of the kingdom of Thibet. Tincal, or crude borax, in the ftate we receive it, is of a dull white or greenifh colour, in irregular cryftals, covered with a rancid oily fubftance, faid to be added to prevent its deliquefcing, and intermixed with earthy impurities. It is not well known in what proportions the component parts exift in the borax when dug out of the earth; becaufe it is faid to be purified by fubfequent folution in water and cryftallization foon after it comes from the mountains: and the borax of commerce is chiefly refined in Holland by a procefs which is kept a fecret; though there is little doubt but it confifts of folution, filtration, cryftallization, and calcination, to free it from the impurities and greafe; and afterwards a fecond folution and cryftallization, probably with an addition of mineral alkali, or falt of foda. M. Chaptal, after trying various

Natural production of tincal or crude borax.

Purification of borax.

* Phil. Tranf. vol. lxxvii. No. 21, 29.

BORAX AND ITS ACID.

processes in the large way, found the method of calcination to be attended with loss; and approves of strong and continued boiling with water, and crystallization, followed by a second solution, ebullition, and crystallization, as the simplest method of purifying this salt *.

Analysis of borax.

If borax be dissolved to saturation in boiling water, and the vitriolic acid be added in such a quantity as to be perceptibly in excess, a salt will be disengaged, during the cooling, in white scales, which will swim at the surface of the fluid. These being taken out, the remaining solution affords Glauber's salt by evaporation. This last salt, consisting of the vitriolic acid united to mineral alkali, affords a proof that the alkali was one of the component parts of the borax: and when, by adding the disengaged scaly salt to mineral alkali in a due proportion, borax is reproduced, we have a complete proof that the scaly salt is the other component part. It was originally denominated sedative salt, but is now known by the name of acid of borax.

The acid of borax may be obtained also by sublimation; the alkaline base being separated by the previous addition of some stronger acid.

Habitudes of borax:

Borax contains a larger proportion of alkali than is necessary to saturate the acid. Some of the alkali is said to be added in the purification of the tincal. This purified salt requires about eighteen times its weight of water to dissolve it, at the temperature of 60°. When heated, it swells up, loses its water of crystallization, and runs into a kind of glass, which

* Elements of Chemistry, Eng. translation, i. 277.

may

may be diffolved in water, and cryftallized, as before.

BORAX AND ITS ACID.

—and its acid.

The acid of borax requires about fifty times its weight of water to diffolve it. In a moderate heat it melts with lefs intumefcence than borax itfelf; and the glaffy fubftance, thus formed, is again foluble in water, having only loft its water of cryftallization.

Borax is ufed as a flux in foldering, and its acid is a very ufeful flux for experiments with the blow-pipe.

Native acid of borax.

The acid of borax has been found uncombined in the waters of certain lakes in Tufcany. There have been feveral accounts of the artificial production of borax faid to be practifed in China, and verified by experiments made in France; but they all want farther confirmation.

Hard cryftallized ftone containing acid of borax.

It has lately been difcovered that a cryftallized ftone, found in a cleft near the top of a ftratified mountain compofed of plafter ftone or gypfum, contains a large proportion of the acid of borax*. This mountain, which bears the name of Kalkberg, is fituated near Luneberg in the duchy of Brunfwick; and the ftone which has been called cubic quartz, but is known to the inhabitants of the vicinity by the name of wurfelftein, is ufually of a white colour, often grey, and fometimes of a violet tinge. Its figure, when perfect, appears at firft fight to be cubic; but, when attentively infpected, is found to be compofed of twenty-fix faces. Moft fpecimens are opake; fome are femi-tranfparent,

* See the Annales de Chimie, ii. 101 and 137, for examinations of this mineral, by M. Weftrumb and by M. Heyer. The former is referred to in the text.

BORAX AND ITS ACID.

Analyfis of the native combination of the acid of borax with lime and magnefia.

and a few are perfectly tranfparent. The greater number of thefe cryftals have the appearance of having been corroded. It is evidently of a laminated texture; though its fracture feems to exhibit a radiated appearance. Its fpecific gravity is about 2.566, and its hardnefs is fuch that it fcratches glafs, and gives fire plentifully with the fteel.

This ftone lofes its tranfparence by ignition, and becomes pulverable if quenched in water; though the hardnefs of its particles caufes it to abrade the hardeft mortars which can be ufed. An extreme degree of heat caufes it to run into a yellow glafs. Water does not diffolve it, either cold or by ebullition. Alkalis act upon it in the dry way, but not readily; and in this operation a confiderable lofs of weight is experienced. Acids, by long boiling upon the pulverized ftone, diffolve it for the moft part. Five days boiling of marine acid upon one hundred grains of the ftone diffolved it at laft.

The folution in marine acid firft exhibited foliated cryftals at its furface, which fell to the bottom; and as the evaporation proceeded, the whole mafs fixed into a yellowifh white fubftance. This was foluble in water, and let fall a fmall portion of filiceous earth. The folution, being examined by the methods of analyfis hereafter to be defcribed, afforded a fmall quantity of iron, with fome lime; and, by the addition of vitriolic acid and fublimation, the acid of borax was obtained. An additional quantity of this fubftance was afforded by wafhing the refidue with the ftrongeft ardent fpirit, and evaporating the folution till cryftals were afforded. The component parts of the ftone were thus found to be be—Acid of borax deprived of its water of cryſtallization by a red heat, 68 parts; magneſia, 13½; lime, 11; clay, 1; calx of iron, 1; ſilex, 2; loſs in the operation, 3½. By adding the mineral alkali to the acid thus obtained, a true borax was formed. BORAX AND ITS ACID.

The acid of borax combines in the humid way with the calcareous, ponderous, and magneſian earths, and alſo with the alkalis, forming compounds hitherto but little examined. It does not directly diſſolve the metals in the humid way; but notwithſtanding its weak affinity, compared with other acids, it is probable that the combinations might be effected by double affinity. It diſſolves ſiliceous earth in the dry way. Spirit of wine diſſolves it, and burns with a green flame when ſet on fire. Combinations of the acid of borax with earths and alkalis.

No attempts have been made to decompoſe this acid, or to exhibit it in the aërial form. Some German chemiſts have lately obtained a metallic ſubſtance by treating borax with charcoal in a ſtrong fire, in the way of reduction. But it is at preſent generally admitted that this metal was iron, from the crucible *. Suppoſed reduction of borax.

* Ruprecht in the Journal de Phyſique for 1790.

CHAP.

CHAP. VI.

OF THE ACID OF SPAR.

ACID OF SPAR.

Fluor or Derbyſhire ſpar.

THE fuſible ſpar, or fluor, which is commonly known in England by the name of Derbyſhire ſpar, contains a peculiar acid united to calcareous earth. The texture of this compound is either ſparry, or irregularly ſhattered or cracked. It is either tranſparent or opake; and the ſpecimens are of a cubic, rhomboidal, polygonal, or irregular figure. The coloured ſpars have the property of becoming phoſphoreſcent, or emitting light, when laid upon a hot iron, or otherwiſe heated; but they loſe this property by being made red hot. This ſpar is not ſufficiently hard to ſtrike fire with the ſteel. It is inſoluble in water, and does not effervcſce with acids.

Diſtillation of the acid.

If the pure fluor, or ſpar, be placed in a retort of lead, with a receiver of the ſame metal adapted, and half its weight of vitriolic acid be then poured upon it, the acid of ſpar will be diſengaged in the aërial form by the application of a gentle heat. This acid air readily combines with water; for which purpoſe it is neceſſary that the receiver ſhould previouſly be half filled with that fluid. When experiments are required to be made with the acid in the claſtic ſtate, it muſt be received over mercury.

Diſtinctive character.

The diſtinguiſhing property which is moſt eminently, and almoſt excluſively, poſſeſſed by this acid, is that of diſſolving ſiliceous earth. The firſt experiments upon it

ACID OF SPAR.

it were made with glafs veffels, and were attended with the fingular phenomenon of an earthy matter being depofited at the inftant that the air came in contact with the water in the recipient. Upon examination it was found to be filiceous earth; and fubfequent experiments proved that it was obtained by corrofion of the glafs, and held in folution by the elaftic fluid. This circumftance fhews the neceffity of ufing metallic veffels in the diftillation. Siliceous earth diffolved.

The fluor acid has been fuccefsfully ufed to make etchings on glafs, in the fame manner as the nitrous acid has long been applied to copper. Etchings on glafs.

With argillaceous earth it forms a neutral falt, of a gelatinous confiftence. With calcareous earth it produces the fpar already treated of. With ponderous earth it forms a falt of difficult folution, which effloresces in the air. It readily combines with magnefia, and forms a cryftallizable falt: it takes this earth from every other known acid. With the vegetable alkali it affords a fufible deliquefcent falt; the folution of which, if fufficiently evaporated, takes a gelatinous appearance. The mineral and volatile alkalis are faid to act nearly in the fame manner. Combinations with earths and alkalis.

This acid acts fcarcely, if at all, upon gold, filver, lead, mercury, tin, antimony, bifmuth, or cobalt, though it diffolves their calces. It acts directly upon iron and zinc, with the production of inflammable air; and it likewife diffolves copper in the metallic ftate, though lefs eafily than when calcined. —with metals.

CHAP.

CHAP. VII.

OF THE ACID OF AMBER.

AMBER.

AMBER is a hard brittle ſubſtance, ſometimes perfectly tranſparent, but moſtly ſemi-tranſparent, clouded, or opake. It is found of all colours, but chiefly yellow or orange. Some ſpecimens contain inſects or leaves. When broken, it preſents a poliſhed ſurface at the place of fracture. It is capable of a good poliſh, though always of a ſomewhat greaſy feel. By friction it becomes electric, and is the ſubſtance in which the operation of electricity was firſt taken notice of by the ancients. It emits an agreeable ſmell when rubbed or heated, and melts at a leſs temperature than is required to cauſe mercury to boil. With acceſs of air it is inflammable; but by diſtillation in cloſed veſſels it affords a ſmall portion of water, a concrete ſublimate which is the acid of amber, and an oil. A gentle heat is ſufficient to raiſe the acid; and care muſt be taken to regulate it ſo as not to drive up the oil, when the acid is required to be had in a ſtate of purity. The acid itſelf is ſoluble in twenty-four parts of cold water, and in a much leſs quantity when boiling hot. The ſublimed acid requires to be purified by repeated ſolutions and cryſtallizations.

Characters of amber:

—where found. Amber is dug out of the earth in the Pruſſian dominions in greater plenty than elſewhere; but the beſt ſort is taken out of the ſea, or is caſt on ſhore by the waves. From its being found in the earth in the neigh-

neighbourhood of foſſil wood, as well as from other circumſtances, it is ſuppoſed to be of vegetable origin. Its analyſis evidently ſhews that it conſiſts of an oil rendered concrete by combination with an acid.

AMBER.

Combinations of the acid of amber.

The acid of amber combines with the earths, alkalis, and metallic calces. With clay it affords a ſalt in cryſtals; with lime and ponderous earth it produces ſalts of difficult ſolubility; and with magneſia, a compound reſembling gum. With the vegetable and volatile alkalis it forms cryſtallizable ſalts, which deliqueſce by expoſure to the air; but with the mineral alkali it forms a ſalt whoſe cryſtals are conſiſtent. With the calces of the metals it forms cryſtals which are for the moſt part permanent.

From its ſublimation in the form of flowers, it is evident that it cannot be exhibited in the aëriform ſtate but at a very elevated temperature. No inquiries have been made in the way of decompoſing it.

CHAP.

CHAP. VIII.

OF PHOSPHORUS AND ITS ACID.

PHOSPHORIC ACID.

Native phosphorus.

THE phofphoric acid, or its bafe, abounds in the animal and vegetable as well as the mineral kingdoms. In this laft it is found united to lead or iron, but perhaps moft abundantly in combination with calcareous earth. It is afferted that there are whole mountains in Spain which confift of a compound of lime and phofphoric acid *. But the acid has been hitherto moft commonly obtained from animal fubftances. Phofphorus is a fubftance greatly refembling fulphur in colour and confiftence, in its ufual ftate of purification; but it is lefs brittle, and much more inflammable. When very pure, it is of a clear tranfparent yellow colour. Like fulphur, it burns with two kinds of flame. An heat of about 60° produces the weaker kind of flame, which fcarcely affords any fenfible degree of warmth. It has the appearance of white fumes in the day light, but is confiderably luminous in the dark. If a veffel containing a fmall piece of phofphorus be furrounded with water gradually heated, the fumes efcape more and more rapidly; and when the water is heated to 160°, the phofphorus takes fire, and burns with a ftrongly vivid and deftructive flame.

Characters of phofphorus.

Page 144.

* Annales de Chimie, i. 196.

This

PHOSPHORUS.

This fubftance, remarkable for its extreme combuftibility, and the exhibition of flame without heat, was firft difcovered about the year 1667, by a chemift whofe name was Brandt. Another chemift, well known by his writings, whofe name was Kunckel, difcovered the fecret of Brandt by a fet of experiments exprefsly inftituted for that purpofe. It is to this philofopher that the world has juftly given the honour of the difcovery. Our eminent Robert Boyle likewife made the difcovery upon the fame information probably as that of Kunckel; namely, that the phofphorus was produced from urine. It is afferted that a certain dealer in fecrets, one Krafft, communicated the procefs to Boyle *; but it is not probable that a man of fuch undoubted integrity as Boyle would have communicated the procefs to the Royal Society as his own, if this had been the cafe. Neither indeed does the invention appear to be of that magnitude, as not to be eafily hit upon by thofe who were determined to fpare no pains nor attention in the purfuit of difcovery, as was the cafe with the chemifts of that day, moft of whom indulged extravagant hopes. The procefs of Boyle confifted in nothing more than diftilling urine till the laft volatile product came over, which is the phofphorus; and he ufed no other artifice to facilitate the operation, than that of firft evaporating the fluid part of the urine until it became of the confiftence of fyrup. He then mixed this liquid with thrice its weight of fine fand, and expofed the whole to diftillation for

The difcovery of phofphorus; by Brandt, Kunckel,

and Boyle.

Defence of Boyle as the inventor.

Procefs of Boyle.

* Stahlii CCC. Exper. ed. Berolini, Ann. 1731, p. 393.

twelve

PHOSPHORUS.

twelve hours, the fire being made as intenſe as poſſible for the laſt ſix hours. Other proceſſes have ſince been invented to ſhorten this operation; but the late diſcovery of Scheele has ſuperſeded them all, on account of its greater expedition and cheapneſs.

Proceſs for obtaining phoſphorus from bones.

The fixed reſidue of bones, after burning, conſiſts of the acid of phoſphorus united to lime. If therefore this white friable ſubſtance be pounded, and paſſed through a ſieve, and a quantity of diluted vitriolic acid be added, leſs than is ſufficient to diſſolve the maſs, it will then conſiſt of a ſolution of ſelenite, with diſengaged phoſphoric acid. By evaporation of the clear liquid, the ſelenite ſeparates in cryſtals; and the decanted liquor, by farther evaporation to dryneſs, and the application of a conſiderable heat, affords the phoſphoric acid in the form of a white or tranſparent glaſs. If this acid be pounded, and mixed with one third of its weight of charcoal, in an earthen retort, it affords phoſphorus by diſtillation.

Phoſphoric glaſs.

The phoſphoric glaſs obtained in the firſt inſtance from bones, is not ſufficiently deprived of calcareous earth to be uſed in any other proceſs than that of making phoſphorus. For this purpoſe however it is not neceſſary to bring it to the conſiſtence of glaſs. The evaporation may be conveniently performed in a copper veſſel; and when the fluid has acquired the conſiſtence of ſyrup, it may be mixed with its own weight of charcoal in powder, and ſubmitted to diſtillation in a good earthen retort. Inſtead of applying a receiver, the neck of the retort may be immerſed in a baſon of water to a ſmall depth; and the phoſphorus, as it comes over, will fall in drops to the

bottom.

bottom. It is true that in the procefs thus managed there will be apparently much phofphorus burned by the admiffion of the common air, which now and then paffes into the neck of the retort, whenever the abforption of the water caufes its furface to fall below the aperture; but this quantity is really inconfiderable, and is compenfated by the fimplicity and facility of the procefs. The operator muft be careful that the neck of the retort be not plunged to too great a depth; becaufe in this cafe the water would pafs into the body of the retort at the time of abforption, before the furface of the water in the bafon had fallen fufficiently to admit the air. The phofphorus comes over as foon as the retort is red hot; and when the drops ceafe, the whole apparatus muft be fuffered to cool. It has the form of reddifh wax, or tallow; and may be preffed together under the water while it is yet warm. If this be done with the naked hand, great care muft be taken that no particle fhall remain fticking to the hands, or under the nails; as fuch a particle, by taking fire when brought into the air, might produce very painful and difagreeable confequences. It may be moulded into fticks, by putting the pieces into fmall conical tubes of glafs, clofed at one end, and fixed upright in a piece of wood, the whole being immerfed under water: on heating the water, the phofphorus will melt, and take the defired form. The impurities that rife to the upper ends of the tubes may be cut off when taken out, which muft not be done till all is cool.

Procefs for obtaining phofphorus.

Page 57.

Phofphorus may be had exceedingly pure by ftraining it through a leather bag immerfed in hot water; or,

Purification of phofphorus.

PHOSPHORIC ACID.

Purification of phosphorus.

or, which is ſtill better, by diſtilling it a ſecond time with a very gentle heat. The blackiſh colour of phoſphorus is aſcribed to a portion of phoſphoric acid which is mixed with it. This diſappears almoſt entirely by boiling with a ſmall quantity of volatile alkali *; and if the phoſphorus be boiled two or three ſucceſſive times in ardent ſpirit, it becomes perfectly tranſparent, and of a beautiful opal colour, with very little loſs of weight.

Phoſphorus muſt be kept in a bottle of water, to prevent its gradual combuſtion.

Phoſphoric acid obtained by ſlow combuſtion.

If a number of ſticks of phoſphorus be placed upright in a glaſs funnel, a piece of glaſs tube being previouſly put into the neck of the funnel to prevent their falling through; and if this funnel be then inſerted in the neck of a bottle containing diſtilled water, the phoſphorus will be decompoſed by the ſlow combuſtion, provided it be expoſed to a temperature higher than that of 60°; and the phoſphoric acid will gradually paſs through the funnel into the water. The acid thus obtained contains a portion of phoſphorus; but, by expoſure to the air, this alſo becomes converted into acid: or the ſuperfluous portion of phoſphorus may be burned by cauſing the acid to boil.

Concrete phoſphoric acid.

Page 208.

If the water be evaporated from the phoſphoric acid, it may be converted by heat into a ſolid tranſparent ſubſtance, which differs from that obtained immediately from bones by the vitriolic acid, in attracting the humidity of the air, and its ſolubility in water. It is ſaid however that a ſtronger heat will render

* Annales de Chimie, i. 234.

it

it permanent, and deprive it of acidity; which change moſt probably ariſes from its combining with the earth of the crucible. PHOSPHORIC ACID.

Phoſphorus may likewiſe be converted into phoſphoric acid by treating it with nitrous acid. In this operation a tubulated retort, with a ground ſtopper, muſt be half filled with concentrated nitrous acid, and a gentle heat applied. Small pieces of phoſphorus being then introduced through the tube, will be diſſolved with an effervefcence, which is produced by the eſcape of a large quantity of nitrous air. This addition of phoſphorus muſt be continued until the laſt piece remains undiſſolved. The fire being then raiſed to drive over the laſt portions of nitrous acid, the phoſphoric acid will be found in the retort; partly in the concrete, and partly in the liquid form. Phoſphoric acid; obtained by the action of nitrous acid:

Vitriolic acid produces nearly the ſame effect as the nitrous; but, being leſs volatile, it is leſs adapted to the purpoſe. —by vitriolic acid:

The ſtrong combuſtion of phoſphorus effects a decompoſition nearly complete, and leaves the acid in a dry ſtate. —by ſtrong combuſtion:

Phoſphoric acid is likewiſe produced by paſſing a ſtream of vital air through phoſphorus liquefied in hot water. —by a ſtream of vital air.

Phoſphorus combines with the cauſtic fixed alkalis in a boiling heat, and forms an hepar; during which a peculiar elaſtic fluid is given out, which poſſeſſes the remarkable property of taking fire as ſoon as it communicates with the air of the atmoſphere. This air has evidently the ſame relation to phoſphorus as the common hepatic air has to ſulphur; and, like Phoſphoric hepar; and air.

Page 142.

that,

PHOSPHORIC ACID.

that, it probably confifts of a folution of the phofphorus in inflammable air.

Combination of phofphorus with fulphur: Sulphur and phofphorus unite by fufion, and form a folid compound of a fetid fmell, which burns with a yellow flame, and fwells in water; at the fame time communicating acidity to that fluid, and emitting a fmell of hepatic air. —with oils: All kinds of oils diffolve phofphorus, and are rendered luminous by it: feveral effential oils form a folution which takes fire by expofure to the air, probably in confequence of the emiffion of phofphoric air. The butter of wax, which confifts of wax deprived of part of its acid by diftillation, is faid to be the propereft material for producing this effect. —ardent fpirits: Very ftrong ardent fpirit diffolves a portion of phofphorus, which gives a perceptible light upon the addition of water. —metals. Metals do not readily combine with this fubftance when fimply heated with it: but when the phofphoric acid, together with charcoal, is expofed to a ftrong heat, a confiderable number of the metals may be made to unite with it *, probably in confequence of their being previoufly calcined by the acid.

Metals revived by phofphorus. When a ftick of phofphorus is plunged in the folutions of gold, filver, copper, and other metals, the phofphorus becomes gradually covered with a brilliant metallic fheath, the phofphorus becoming acidified as the metal is revived.

Ufes of phofphorus. Phofphorus has not yet been applied to any ufe, excepting that a few trials have been made of its efficacy in medicine. The luminous appearance of

* Journal de Phyfique, for March 1789.

writing

writing made of a ftick of phofphorus upon paper, or any other fubftance which can abrade it, is fufficiently known. There is fome danger of its catching fire if the friction be fwift or violent ; and for that reafon the ftick of phofphorus ought to be held in a metallic cafe, and a cup of water fhould be at hand to plunge it in. It is alfo ufed when diffolved in effential oils, or butter of wax, to make tapers or matches, intended to fupply the place of flint and fteel in producing light; but it is not probable that thefe will ever be afforded fufficiently cheap to anfwer the purpofe of a fubftitute to that operation.

PHOSPHORIC ACID.

Phofphoric matches.

The acid of phofphorus exifts, as has been already obferved, in two ftates fimilar to thofe of the volatile and fixed vitriolic acids: and the difference between thefe ftates arifes likewife from a fimiliar caufe ; namely, that a part of the phofphorus is not converted into acid, but is held in folution by that part which is acidified. Neither of the kinds of phofphoric acid rifes totally by heat like the volatile vitriolic acid : but that which contains phofphorus emits white fumes, which feem to confift of part of the acid combined with the redundant phofphorus ; and the refidue melts into the vitreous form. This difference between the vitriolic and phofphoric acids depends no doubt upon the greater degree of fixity of the latter.

Two ftates of phofphoric acid.

Page 144. 152.

The phofphoric acid does not appear to act upon filiceous earth, though it corrodes glafs when hot. It unites with clay in the dry way. With calcareous earth it forms a combination fcarcely foluble in water, unlefs there be an excefs of acid : it has been already noticed that the earthy refidue of bones confifts of

Combinations of phofphoric acid.

 this

PHOSPHORIC ACID.

this ſubſtance. With ponderous earth it forms a ſalt whoſe properties are little known; and with magneſia it forms a cryſtallizable compound of difficult ſolubility.

Combinations of phoſphoric acid with alkalis.

This acid, when in combination with the vegetable alkali, forms a very ſoluble ſalt, which is ſuſpended in conſiderably greater quantity in hot than in cold water. It ſeparates from the liquid in cryſtals, either by cooling or evaporation. The combination of phoſphoric acid with mineral alkali conſtitutes a ſalt of an agreeable taſte, reſembling that of common ſalt. It is not eaſily cryſtallized, by reaſon of its diſpoſition to form an adheſive matter by evaporation, which reſembles gum. A ſmall exceſs of alkali renders it more diſpoſed to cryſtallize, and cauſes it to effloreſce by expoſure to the air. This ſalt has been lately introduced into medicine. The combination of volatile alkali with phoſphoric acid is likewiſe more ſoluble in hot than in cold water, and affords cryſtals by cooling. An exceſs of alkali renders the cryſtallization more eaſy. It is greatly diſpoſed to fly off by a gentle heat.

Phoſphoric ſalts from urine.

The phoſphoric ſalts were firſt obtained from urine. This animal fluid conſiſts of a large quantity of water; the acids of phoſphorus and of the calculus of the bladder, both in a diſengaged ſtate; ſome common ſalt, with the ſaline combinations of the phoſphoric acid with lime, mineral alkali, and volatile alkali; and two kinds of extractive matter, one of which is ſoluble in ardent ſpirit, and the other in water. When urine is expoſed to evaporation by heat, it aſſumes a darker colour; and a pulverulent matter falls down, which

PHOSPHORIC ACID.

which confifts of the calcareous phofphoric falt, and the acid of the human calculus. If the urine be filtered as foon as it has acquired a vifcid confiftence, it affords faline cryftals by cooling. Thefe confift of the common falt, and alfo of a triple combination of phofphoric acid with the mineral and vegetable alkalis, which is generally known by the name of microcofmic falt. Repeated evaporations and coolings are required to deprive urine of the moft part of its falts. Subfequent folution in water, heated and cooled in clofed veffels, purifies the phofphoric cryftals, and feparates the falt with the bafe of volatile alkali from that which contains mineral alkali. As the former of thefe falts only is decompofed by heating with charcoal, it is from this alone that the phofphorus of urine is obtained. The combination of mineral alkali with phofphoric acid was for fome time fuppofed to be a peculiar acid, and was called the perlate acid.

Salts from urine.

Microcofmic falt.

Perlate acid.

The microcofmic falt has been applied to great ufe by the celebrated Bergman, as a flux in blow-pipe experiments.

Phofphoric acid unites with feveral of the metallic calces. It acts upon oils, to fome of which it communicates a peculiar flavour, and it thickens others. It has not been well decided whether it can be exhibited in the elaftic ftate at the temperature of the atmofphere.

Combinations of phofphoric acid with metals and oils.

The faline compounds formed by the phofphoric acid, when not totally acidified, appear to differ from thofe of the complete acid; but few experiments have been made with thefe.

The theory of the converfion of phofphorus into an

Theory.

PHOSPHORIC ACID.

Theory.

an acid, and the reduction into its original ſtate by treatment with charcoal, is perfectly ſimilar to that of ſulphur and vitriolic acid. When phoſphorus is burned, there is an abſorption of vital air, at the ſame time that phlogiſton, or the principle of inflammability, is ſuppoſed to be extricated. In this manner the phoſphorus is converted into an acid, which, when water is not preſent, has the appearance of white flakes; and in every ſtate weighs conſiderably more than the phoſphorus itſelf. On the other hand, when phoſphoric acid is heated with charcoal, the vital air is abſorbed by the latter; at the ſame time that the phoſphoric baſis is ſuppoſed to receive phlogiſton from the charcoal, and by that means recovers its original ſtate. According to the new theory, the phoſphorus is conſidered as a ſimple ſubſtance, relatively to the preſent ſtate of our knowledge; its converſion into an acid being ſuppoſed to conſiſt merely in the abſorption of vital air, and its revivification in the diſengagement of that ſubſtance.

CHAP.

CHAP. IX.

OF THE METALLIC ACIDS; OF ARSENIC, OF MOLYBDENA, AND OF TUNGSTEN, OR WOLFRAM.

ACIDITY.

Retrofpect of the facts and doctrines contained in the prefent fection.

IN the preceding chapter we have exhibited a number of inftances in which the procefs of combuftion has converted inflammable fubftances into acids: whence it may be inferred, as a general rule, that acidity is the ftate of a combuftible body, which is burned, either completely or nearly fo; whether fuch combuftion be made to confift in the difengagement of phlogifton and abforption of pure air, or whether it be ftated fimply as the latter effect. We have feen that fulphur, which is highly inflammable, becomes converted into vitriolic acid air, which is not at all inflammable; and that, when completely burned, it becomes vitriolic acid, in which the peculiar properties of that clafs of bodies are moft eminently feen. Phlogifticated air, which, by reafon of its flight tendency to unite with vital air, appears to require either a long expofure to that fubftance, or the fucceffive ignition of its parts by electricity, is found to form nitrous air when the combuftion is incomplete—a fubftance which has no acid properties; but which becomes nitrous acid of various degrees of acidity, according to the dofe of vital air it may be combined with, and perhaps the extrication of phlogifton. The metals have been fhewn to be combuftible, as well by the

METALLIC ACIDS.

Acidification of metals.

the action of acids, as by heating them with accefs of pure air. When they are thus calcined, they become foluble in acids. Some of the metallic bodies have been difcovered to be fufceptible of a farther continuation of the procefs by which they are calcined; and this continuation is found to change them into acids foluble in water, and difpofed to combine with and neutralize alkaline fubftances. Hence there feem to be certain periods of combuftion at which the fame fimple bafis becomes fucceffively converted into a calx, or fubftance capable of neutralizing acids; and afterwards into one which combines with and neutralizes alkalis.

General inferences; by conjecture.

If we might generalize this, it would be fair to conclude that all metals are, in their own nature, capable of being converted into acids; that all acids are reducible to inflammable fubftances, though art has not yet devifed the means of doing it in every inftance; and it might be conjectured that the fixed alkalis themfelves may confift of combinations of inflammable fubftances with pure air, to which they may adhere with too ftrong an affinity to be feparated by means of any medium we are acquainted with.

Metals acidified.

The metallic fubftances which have been acidified are, arfenic, molybdena, and wolfram.

Arfenic.

Arfenic is a fubftance which combines with and mineralizes many of the metals, and is fublimed from them in the form of a white calx. It is not clearly afcertained, in a number of inftances, whether the arfenic be combined with this calx, or with the metal, or with the acid it is capable of being converted into. If this white calx be diffolved in three times its weight of of boiling muriatic acid in a tubulated retort, and twice its weight of nitrous acid be then added, and the evaporation ſtill continued, the former acid will fly off in the elaſtic ſtate; while the nitrous acid will be decompoſed, and will convert the arſenic into a concrete acid. The purity of this may be aſcertained by igniting it; for this degree of heat will drive off any portion of the other acids that may remain.

METALLIC ACIDS.

Proceſs for obtaining the arſenical acid.

The arſenical acid is much more fixed in the fire than the calx itſelf; it may even be fuſed into a tranſparent glaſs. It is ſlightly deliqueſcent, and requires twice its weight of water to diſſolve it. This acid forms a ſaline combination with argillaceous earth, which coagulates as ſoon as it arrives at the point of ſaturation. With lime it forms a cryſtallizable ſalt. With ponderous earth it forms a ſalt of difficult ſolubility. With magneſia it produces a coagulum, or gelatinous ſubſtance. It does not act upon ſiliceous earth, unleſs perhaps in the dry way.

Characters of arſenical acid.

Combinations with earths;

The combination of this acid with vegetable alkali forms a deliqueſcent ſalt, which does not cryſtallize; but if there be a ſmall exceſs of the acid, the ſolution will afford fine cryſtals, which are the neutral arſenical ſalt of Macquer. The mineral alkali, ſaturated with arſenical acid, affords a cryſtallizable ſalt nearly reſembling the foregoing. It unites likewiſe with the volatile alkali, and forms a ſalt in cryſtals. When this is expoſed to diſtillation, part of the alkali is decompoſed; phlogiſticated air is given out; and the acid, being reduced to the calciform ſtate, ſublimes.

—with alkalis.

Page 128.

Mere heat in an open veſſel gradually reduces the acid of arſenic to the ſtate of calx, which ſublimes.

 When

METALLIC ACIDS.

Reduction of arsenical acid.

When the fluid acid is digested with charcoal powder, no change takes place until the moisture is evaporated; and when the heat is raised to ignition, a sudden combustion takes place, all the acid is reduced and sublimed into the neck of the retort, the greater part being in the form of the metallic regulus, and the rest calx.

Combination with sulphur.

Continued digestion with oils revives this acid. It unites with sulphur by fusion, the whole mass rising almost instantly in the form of a red sublimate, at the same time that volatile sulphureous acid passes into the receiver.

Theory.

The theory of these facts will not be difficult to the reader who has attentively considered the preceding chapters. The white calx of arsenic was dissolved in marine acid; because it is required to be had in a state of extreme division, and because the nitrous acid can only dissolve it very sparingly. The nitrous acid is added; because it readily gives out vital air (and perhaps absorbs phlogiston), while it becomes converted into nitrous air, which flies off. The calx of arsenic thus becomes completely acidified. This acid, at a strong temperature, decomposes volatile alkali, which is a compound of phlogisticated and inflammable air. This last principle either affords phlogiston to the acid, and reduces it to the state of a calx; or, according to the new theory, performs the same thing by uniting with the vital air, and forming water. And a similar explanation will serve for the effects of charcoal, or oils, which either afford phlogiston, or absorb the vital air. With respect to the effects of sulphur, part of it is acidified by combustion, or combination with the vital air of the acid, and comes over in the form

form of vitriolic acid air; while the rest combines with the arfenic, which is reduced, but in what degree does not clearly appear.

Characters of molybdena.

Molybdena is a fubftance which greatly refembles plumbago, or black lead; but its texture is fcaly, and it is not eafily pulverifed, on account of a degree of flexibility which its laminæ poffefs. If it be triturated in a mortar with vitriolated tartar, this faline fubftance will, by the hardnefs and angular figure of its particles, render it more eafily pulverable; and when this purpofe is accomplifhed, the falt may be wafhed away by feveral affufions of water. If the powder be then placed in a retort, with five or fix times its weight of diluted nitrous acid, and diftillation be carried on to drynefs, it is found that volatile vitriolic acid and nitrous air are extricated, and the colour of the refidue becomes lighter. More acid muft then be added, and the diftillation again repeated till the fourth or fifth time. A ftrong heat is required to drive off the laft portions of vitriolic acid formed by the fulphur. When no more red vapours appear, the refidue will be white and pulverulent, refembling chalk. This is the acid of molybdena. It requires near five hundred times its weight of boiling water to diffolve it, and exhibits weak acid properties.

Procefs for obtaining the acid of molybdena.

Combinations.

This acid combines with lime, magnefia, and calcareous earth, with which it forms falts of very difficult folution. When added to a folution of ponderous earth in the nitrous or marine acids, it forms a compound which is fparingly foluble in cold water; and, on that account, falls to the bottom. The combination

METALLIC ACIDS.

tion of this acid with vegetable alkali is more foluble in water than the acid itfelf, and affords cryftals by evaporation. It unites likewife with the volatile alkali. Several of the metals, when diffolved, are likewife feized by this acid, and precipitated from their folutions.

Regenerated molybdena.

When the acid of molybdena is heated with fulphur in a retort, placed in fuch a manner as that the fublimed fulphur may melt and run back again, a combination between thefe two fubftances is at length produced; and the fuperfluous fulphur flies off, being partly converted into volatile vitriolic acid. The refidue is found to be in every refpect the fame as the native molybdena. The analyfis of molybdena by the nitrous acid fhewed that it confifts of fulphur united to a peculiar acid, or acid bafis; and this fynthetical production of molybdena proves the fame thing.

Acid of tungften, or wolfram.

The acid of tungften, or wolfram, is a peculiar metallic fubftance obtained from thefe minerals. The tungften is a ponderous ore, of a grey colour, and lamellar texture. It confifts of the metallic calx, or acid, united to about its own weight of calcareous earth. Wolfram is a mineral of ftill greater fpecific gravity, which is formed in the tin mines of Cornwall, and elfewhere. It is of a brownifh black colour, of a radiated or foliated texture, internally fhining almoft with the luftre of a metal. It is of a moderate hardnefs, though fometimes fo friable as to be pulverable between the fingers. It contains about two-thirds of the peculiar calx or acid; and the reft

METALLIC ACIDS.

Procefs for obtaining the acid of tungften, or wolfram.

reft confifts chiefly of the calces of manganefe and iron. If either of thefe minerals be pulverized and digefted in the vitriolic, nitrous, or marine acids (but the latter is the moft effectual), the calcareous earth of the tungften, or the manganefe and iron of the wolfram, which lie on the external furfaces of the particles, will be diffolved; and the wolfram calx, being laid bare, will exhibit a yellow colour. The refiduum, after edulcoration, or wafhing with water, being digefted with volatile alkali, the wolfram calx, or acid, will be taken up, or extracted from the furface, in the fame manner; the yellow colour vanifhing at the fame time. This refidue, after edulcoration, will again prefent a furface to be acted upon by the marine acid, which will feize another ftratum of particles, that in the former digeftion were defended by the wolfram calx, which was afterwards taken up by the volatile alkali. In this manner, by the alternate application of volatile alkali and marine acid, the mineral will at length be almoft entirely diffolved. The portions of acid are found to contain either the calces of manganefe and iron, or elfe calcareous earth, according to the mineral made ufe of; and the alkaline folvent contains the acid of wolfram. The addition of nitrous acid to this laft fluid precipitates a falt which has acid properties, and is fparingly foluble in water. The firft difcoverer * called it the acid of tungften, though in fact it contains both volatile alkali and nitrous acid. It may however be deprived of thefe laft by calcination, and is then of a brimftone yellow colour.

* Scheele.

The

METALLIC ACIDS.

The yellow colour produced by applying marine or nitrous acid in a digefting heat, affords an eafy method of diftinguifhing fuch minerals as contain wolfram.

Procefs for obtaining the acid of tungften, or wolfram.

In the dry way, if the vegetable alkali be fufed with either of thefe minerals, it takes up the calx or acid. This being diffolved in water, filtered, and evaporated to drynefs, muft be boiled in nitrous acid on a fand bath. The acid takes up the alkali, and may be decanted off. A repetition of this boiling for two or three times with frefh acid, will effectually carry off the whole of the alkali; and the adhering acid may be driven off by calcination in a cupelling furnace. The powder is then yellow, and does not differ from that obtained by the diftillation of volatile alkali in the moift way.

Characters of the acid.

This matter is not foluble in water; but when triturated in that fluid it forms an emulfion, which paffes through the filtre, and does not completely fubfide in the courfe of three months. This does not form an emulfion with acids. Pure vegetable alkali diffolves it, as has been already obferved; but the produce has always an excefs of alkali. If more nitrous acid be added than is fufficient to faturate the alkali, a precipitate falls down, which confifts of acid, alkali, and wolfram calx. The addition of lime to this, or to the precipitate from volatile alkali, produces a regenerated tungften, or combination of lime with the wolfram calx or acid; and the alkali, together with the nitrous acid, is found in the fupernatant fluid.

It

METALLIC ACIDS.

It is ſeen * therefore that this yellow matter is either an acid, or in a ſtate nearly approaching to acidity: for it is not combinable with acids, and unites readily to alkalis and calcareous earth.

Arſenic, molybdena, and wolfram, are reducible to the metallic ſtate, and will again come under our inſpection when we treat of that claſs of bodies.

* The beſt account of this ſubſtance is to be found in "De Luyart's Chemical Analyſis of Wolfram," of which a tranſlation was printed in London, 1785, with Scheele and Bergman's papers prefixed.

BOOK II.

PARTICULAR CHEMISTRY.

SECTION III.

OF METALLIC BODIES.

CHAP. I.

CONCERNING GOLD.

GOLD.

Characters of gold.

GOLD is a yellow metal, of much greater ſpecific gravity than any other body in nature, except platina. It is ſoft, very tough, ductile, and malleable; unalterable and fixed, whether expoſed to the atmoſphere, or to the ſtrongeſt heat of furnaces. The moſt powerful burning mirrors are ſaid to have volatilized it; and it has been driven up in fumes, in the metallic ſtate, by flame urged upon it by a ſtream of dephlogiſticated air. The electric ſhock converts it into a purple calx, as may be ſeen by tranſmitting

that

GOLD. Obvious properties.

that commotion through gold leaf between two plates of glaſs; or by cauſing the exploſive ſpark of three or more ſquare feet of coated glaſs to fall upon a gilded ſurface. A ſtrong heat is required to melt it, which does not happen till after ignition. Its colour when melted is of a blueiſh green; and the ſame colour is exhibited by light tranſmitted through gold leaf.

Extreme ductility and tenacity.

The limits of the ductility and malleability of gold are not known; and its tenacity exceeds that of any other metal. A gold wire, of one tenth of an inch diameter, requires 500lb. weight to break it.

Manufacture of gold leaf:

The method of extending gold, uſed by the gold-beaters, conſiſts in hammering a number of thin rolled plates between ſkins or animal membranes. By the weight and meaſure of the beſt wrought gold leaf, it is found that one grain is made to cover 56$\frac{3}{4}$ ſquare inches; and from the ſpecific gravity of the metal, together with this admeaſurement, it follows, that

—its thickneſs.

the leaf itſelf is $\frac{1}{282000}$ part of an inch thick. This however is not the limit of the malleability of gold; for the gold-beaters find it neceſſary to add three grains of copper in the ounce to harden the gold, which otherwiſe would paſs round the irregularities of the neweſt ſkins, and not over them; and in uſing the old ſkins, which are not ſo perfect and ſmooth, they proceed ſo far as to add twelve grains. The

Gilt wire.

wire which is uſed by the lace-makers is drawn from an ingot of ſilver, previouſly gilded. In this way, from the known diameter of the wire, or breadth when flattened; and its length, together with the quantity of gold uſed; it is found by computation that

that the covering of gold is only $\frac{1}{12}$ part of the thickness of gold leaf; though it still is so perfect as to exhibit no cracks when viewed by a microscope. GOLD.

Solvents. No acid acts readily upon gold but aqua regia and the dephlogisticated marine acid. The vitriolic acid distilled from manganese has some action upon it; as have likewise the pale nitrous acid, and the phosphoric acid when boiling.

Aqua regia. The small degree of concentration which the dephlogisticated marine acid is susceptible of, and the imperfect action of the latter acids, render aqua regia the most convenient solvent for this metal.

Solution of gold. When gold is immersed in aqua regia, an effervescence takes place with the escape of air, which has not been examined; the solution tinges animal matters of a deep purple, and corrodes them. By careful evaporation, fine crystals of a topaz colour are obtained. The gold is precipitated from its solvent by a great number of substances. Lime and magnesia precipitate it in the form of a yellowish powder. Alkalis exhibit the same appearance; but an excess of alkali redissolves the precipitate. The precipitate of gold obtained from aqua regia by the addition of a fixed alkali, appears to be a true calx, and is soluble in the vitriolic, nitrous, and marine acids; from which however it separates by standing, or by evaporation of the acids. The nut gall precipitates gold of a reddish colour, very soluble in the nitrous acid, to which it communicates a fine blue colour.

Precipitates: —by earths and alkalis:

—volatile alkali. The volatile alkali precipitates the solution of gold much more readily than fixed alkalis. This precipitate, which is of a brown, yellow, or orange colour,

GOLD.

Production of fulminating gold:

possesses the property of detonating with a very considerable noise when gently heated. It is known by the name of fulminating gold. The presence of volatile alkali is necessary to give the fulminating property to the precipitate of gold; and it will be produced by precipitating it by fixed alkali from an aqua regia previously made by adding sal ammoniac to nitrous acid, or by precipitating the gold from pure aqua regia by means of sal ammoniac instead of the volatile alkali alone. The fulminating gold weighs one fourth more than the gold made use of. A considerable degree of precaution is necessary in preparing this substance. It ought only to be dried in the open air, at a distance from a fire, because a very gentle heat may cause it to explode. Several fatal accidents have arisen from its explosion, in consequence of the friction of ground stoppers in bottles containing this substance, of which a small portion remained in the neck.

Analysis.

Page 50.

Fulminating gold, when exposed by Berthollet to a very gentle heat in a copper tube, with the pneumatical apparatus of mercury, was deprived of its fulminating quality, and converted into a calx, at the same time that alkaline air was disengaged. From this dangerous experiment it is ascertained that fulminating gold consists of calx of gold, combined with the volatile alkali. The same eminent philosopher caused fulminating gold to explode in copper vessels. Phlogisticated air was disengaged, a few drops of water appeared, and the gold was reduced to the metallic form. From this experiment he infers that the volatile alkali was decomposed; that the phlogisticated air, suddenly

denly aſſuming the elaſtic ſtate, cauſed the exploſion; while the vital air of the calx united with the inflammable air of the alkali, and formed the water.

Theory.

This ſatisfactory theory was ſtill further confirmed by that decompoſition of fulminating gold, which takes place in conſequence of the action of the concentrated vitriolic acid, of melted ſulphur, fat oils, and ether; all which deprived it of its fulminating quality by combining with its volatile alkali.

Precipitation of gold by liver of ſulphur:

Liver of ſulphur precipitates gold from its ſolvent; the alkali uniting with the acid, aud the gold falling down, combined with the ſulphur; of which however it may be deprived by moderate heat.

—by metallic ſubſtances.

Moſt metallic ſubſtances precipitate gold from aqua regia; lead, iron, and ſilver precipitate it of a deep and dull purple colour; copper and iron throw it down in its metallic ſtate; biſmuth, zinc, and mercury, likewiſe precipitate it. A plate of tin immerſed in a ſolution of gold affords a purple powder, called "the purple powder of Caſſius," which is uſed to paint in enamel. There are various methods of managing this proceſs. That deſcribed by Macquer conſiſts in diſſolving tin by very ſmall portions at a time without heat, in an aqua regia compoſed of two parts of nitrous, and one of marine acid, previouſly weakened with water equal in weight to both the acids. The firſt ſmall portion of tin muſt be ſuffered to be entirely diſſolved before a ſecond is added. This addition muſt be continued till the acid has acquired a yellow colour, and ſcarcely acts at all upon the tin laſt added.

Proceſs for making the purple powder of Caſſius.

GOLD.

Procefs for making the purple powder of Caffius.

On the other hand, the pureft gold muft be diffolved in an aqua regia compofed of three parts of nitrous and one of marine acid. This folution may be made as expeditioufly as the operator choofes by the affiftance of the heat of a fand bath.

The folution of tin muft then be largely diluted; as, for example, with one hundred parts of diftilled water; and a fmall quantity of this may then be affayed by feparating it into two parts, and diluting one of the parts ftill farther. Upon trial of both, by letting fall a drop of the folution of gold into each, it will be feen which affords the moft beautiful purple precipitate. The whole of the folution of tin muft accordingly be altered, if neceffary, by adding more water. Pour into this folution, in a large glafs or earthen veffel, nearly half as much of the folution of gold as it contains of folution of tin, ftirring the mixture with a glafs ftick. In a fhort time the liquor will become of a beautiful red colour, which will gradually difappear by the fubfidence of the precipitate. By adding a fmall quantity of folution of tin, it will be feen whether the whole of the gold is precipitated. The clear liquor muft then be decanted, and the precipitate wafhed. It confifts of the calces of gold and tin in combination, and is the only known fubftance which has the property of communicating a purple colour to glafs.

Obfervations.

The difficulties attending the preparation of this article appear to depend on the ftate of the tin. If the folution of this metal be made with heat and rapidity, it becomes too much calcined to adhere to the

the acid, or to precipitate the gold; and the combination of the two metals which falls down, varies in colour accordingly as this term is approached. Thefe are the chief circumftances; but there is no doubt that a complete examination of the procefs would indicate others worthy of notice.

Solutions of gold in ether, &c.

Ether, naptha, and effential oils, take gold from its folvent, and form liquors which have been called potable gold. The gold which is precipitated by evaporation of thefe fluids, or by the addition of martial vitriol to the folution of gold, is of the utmoft purity.

Gold refifts nitre:

In the dry way, gold refifts the action of neutral falts, more efpecially nitre, which deflagrates with the imperfect metals. Nitre however does not afford an expeditious way of purifying gold, becaufe this metal in fome meafure protects and covers the alloys from its action. It is remarked that borax, ufed as a flux with gold, renders it paler; and that this alteration of colour difappears by the addition of nitre, or common falt. As the acid of borax forms a compound with gold, which falls to the bottom when this acid is added to the metal in folution, it is probable that the palenefs produced by borax may arife from the combination of a fmall portion of its acid with the gold, which might be driven off by a continuance of the heat; and unites by ftronger affinity with the alkali of the nitre, or of the common falt, in proportion as their acids are diffipated by heat.

—but is rendered pale by borax:

—unchanged by earths, alkalis, or fulphur.

Earths and alkalis do not act on gold in the dry way. Sulphur, which combines with moft metals, has no effect on this. A procefs called dry parting

is

GOLD. Procefs of dry parting.

is grounded on this property, and is more efpecially ufed in feparating filver from gold, when the quantity of this latter metal is too fmall to anfwer the charges of diffolving the larger mafs of filver in nitrous acid. For this purpofe, the mixed metal is fufed, and flowers of fulphur thrown on its furface. This combines with the filver in the form of a black fcoria; while the gold remains at the bottom in its metallic ftate. The operation of dry parting does not leave the gold in a ftate of purity; becaufe the laft portions of filver are defended from the action of the fulphur. But when the quantity of filver is thus diminifhed, the operation of parting with aqua fortis, or nitrous acid, may be advantageoufly ufed.

Combination with liver of fulphur:

Liver of fulphur diffolves gold in the dry way. Equal parts of fulphur and vegetable alkali are to be haftily fufed with one fourth of a part of gold leaf. This combination is foluble in water, with which it forms a yellowifh green folution. By the addition of an acid the gold is thrown down in combination with the fulphur; of which it may be deprived by heat.

—with metals.

Moft metals unite with gold by fufion. With filver it forms a compound, which is paler in proportion to the quantity of filver added. It is remarkable that a certain proportion, for example a fifth part, renders it greenifh. From this circumftance, as well as from that of a confiderable proportion of thefe metals feparating from each other by fufion, in confequence of their different fpecific gravities, when their proportions do not greatly differ, it fhould feem that their union is little more than a mere mixture, without combination.

tion. For as gold leaf tranfmits the green rays of light, it will eafily follow, that particles of filver, enveloped in particles of gold, will reflect a green inftead of a white light.

GOLD.

A ftrong heat is neceffary to combine platina with gold; it greatly alters the colour of the gold if its weight exceed the forty-feventh part of the mafs: it does not much affect the ductility. The Spanifh miniftry has prohibited the exportation of platina from America, left it fhould be ufed in adulterating gold; but this does not appear to be a danger which need be feared, as chemiftry has long been in poffeffion of feveral fimple and expeditious methods of diftinguifhing this fraud, which befides is evident to the fight when the quantity of debafement is confiderable. It may be queftioned, likewife, whether the value of platina would not foon exceed that of gold, if its properties and ufes were better known in fociety.

Combinations with metals. Platina.

Vide p. 233, and alfo chap. iii. of this fection.

Mercury is ftrongly difpofed to unite with gold in all proportions, with which it forms an amalgam: this, like other amalgams, is fofter, the larger the proportion of mercury. It foftens and liquefies by heat, and cryftallizes by cooling.

Mercury:

Lead unites with gold, and confiderably impairs its ductility. Copper renders gold lefs ductile, harder, more fufible, and of a deeper colour. This is the ufual addition in coin, and other articles ufed in fociety. Tin renders it brittle in proportion to its quantity; but it is a common error of chemical writers to fay that the flighteft addition is fufficient for this purpofe. With iron it forms a grey mixture, which obeys the magnet. This metal is very hard, and is faid

—lead, copper, &c.

Alchorne in Phil. Tranf. vol. lxxv.

GOLD.

Combinations with metals.

faid to be much fuperior to fteel for the fabrication of cutting inftruments. Bifmuth renders gold white and brittle; as do likewife nickel, arfenic, and antimony. Zinc produces the fame effect; and, when equal in weight to the gold, a metal of a fine grain is produced, which is faid to be well adapted to form the mirrors of reflecting telefcopes, on account of the fine polifh it is fufceptible of, and its not being fubject to tarnifh. The alloys of gold with the regulus of manganefe or molybdena are not known. It could not be mixed with the regulus of wolfram, on account of the infufibility of this laft fubftance.

Native ores, or alloys of gold.

Gold is found moftly in the metallic ftate, though generally alloyed with filver, copper, iron, or all three. It is found either in feparate lumps, or vifible grains, among the fands of rivers in many parts of Europe, and elfewhere. The quantity is for the moft part infufficient to pay the coft of feparating it; but it is thought to be more univerfally diffufed in fands and earths than any other metal, except iron. The greateft quantity of gold is imported into Europe from South America. Some is brought from the Eaft Indian iflands and China, and fome from the coaft of Africa. The principal gold mines in Europe are

Purification.

thofe of Hungary. Some fands afford gold by fimple wafhing; the heavy metallic particles fubfiding fooneft: but when it is bedded in earths or ftones, thefe fubftances are pounded, and boiled with one tenth of their weight of mercury, together with water. The mercury, after a certain time, abforbs the gold, and may be feparated by preffure through leathern bags, and fubfequent diftillation. Or otherwife, if the fand be heated red hot, and quenched in water several times, for the purpose of cracking and dividing it, and the whole be then melted into glass, with twice its weight of the calx of lead, called litharge, and charcoal powder be then added, the lead will be revived into the metallic state, and will carry the gold along with it. By exposure to a proper degree of heat, with access of air, the lead may again be converted into litharge, and the gold will be left pure. This last operation is in fact a method of assaying sands which contain gold, rather than of obtaining it from them in the large way.

Auriferous sands.

Gold is also found in certain martial pyrites in Sweden and elsewhere; from which it may be extracted by torrefaction, or burning of the sulphur, and subsequent digestion in aqua regia.

Pyrites containing gold.

To obtain gold in a state of purity, or to ascertain the quantity of alloy it may contain, it is exposed to a strong heat, together with lead, in a porous crucible. This operation is called cupellation, and is performed as follows: The precious metal is put, together with a due proportion of lead, into a shallow crucible made of burned bones, called a cupel; and the fusion of the metals is effected by exposing them to a considerable heat in a muffel, or small earthen oven, fixed in the midst of a furnace. The lead continually vitrifies, or becomes converted into a glassy calx, which dissolves all the imperfect metals. This fluid glass, with its contents, soaks into the cupel, and leaves the precious metal in a state of purity. During the cupellation, the scoriæ running down on all sides of the metallic mass produce an appear-

Cupellation of gold.

GOLD.

appearance called circulation; by which the operator judges whether the procefs is going on well. When the metal is nearly pure, certain prifmatic colours flafh fuddenly acrofs the furface of the globule, which foon afterward appears very brilliant and clean: this is called the brightening, and fhews that the feparation is ended.

Separation of gold from the perfect metals: After gold has paffed the cupel, it may ftill contain either of the other perfect metals, platina or filver. The former is feldom fufpected; the latter is feparated by the operations called quartation and parting. —by quartation: Quartation confifts in adding three parts of filver to the fuppofed gold, and fufing them together; by which means the gold becomes one fourth of the mafs only. The intention of this is to feparate the particles of gold from each other, fo that they may not cover and defend the filver from the action of the pure nitrous acid, which is to be ufed in the procefs of parting. —and parting. Parting confifts in expofing the mafs, previoufly hammered, or rolled out thin, to the action of boiling aqua fortis of a due ftrength. If the acid be not too concentrated, it diffolves the filver, and leaves the gold in a porous mafs of the original form; but, if too ftrong, the gold is in a powdery form, which may be wafhed and dried. The weight of the original metal before cupellation, and after all the fubfequent ftages, ferves to afcertain the degree of finenefs of the ingot, or ore, of which it was a part.

Finenefs of gold. The quantity of alloy is never confidered as part of the value of metals which contain either gold or filver. In eftimating or expreffing the finenefs of gold, the whofe mafs fpoken of is fuppofed to weigh twenty-four

GOLD.

four carats of twelve grains each, either real or merely proportional, like the aſſayer's weights; and the pure gold is called fine. Thus, if gold be ſaid to be 23 carats fine, it is to be underſtood, that in a maſs weighing 24 carats the quantity of pure gold amounts to 23 carats.

The aſſay of ſmall work, by the touch.

In ſuch ſmall works as cannot be aſſayed by ſcraping off a part and cupelling it, the aſſayers endeavour to aſcertain its quality, or fineneſs, by the touch. This is a method of comparing the colour and other properties of a minute portion of the metal with thoſe of certain ſmall bars whoſe compoſition is known. Theſe bars are called touch-needles; and they are rubbed upon the black baſaltes, which for that reaſon is called the touchſtone. Black flint, or pottery, will ſerve the ſame purpoſe. Sets of golden needles may conſiſt of—pure gold; pure gold $23\frac{1}{2}$ carats, with half a carat ſilver; 23 carats gold, with one carat ſilver; $22\frac{1}{2}$ carats gold, with $1\frac{1}{2}$ carat ſilver; and ſo forth, till the ſilver amounts to four carats; after which the additions may proceed by whole carats. Other needles may be made in the ſame manner, with copper inſtead of ſilver; and other ſets may have the addition conſiſting either of equal parts ſilver and copper, or ſuch proportions as the occaſions of buſineſs require.

Touch-needles.

Obſervations on the aſſay by the touch.

In foreign countries, where trinkets and ſmall work are required to be ſubmitted to the aſſay of the touch, a variety of needles are neceſſary; but they are not much uſed in England. They afford however a degree of information which is more conſiderable than might at firſt be expected. The attentive aſſayer not only compares the colour of the ſtroke made upon the

GOLD.

Aſſay by the touch.

the touchſtone by the metal under examination with that produced by his needle, but will likewiſe attend to the ſenſation of roughneſs, dryneſs, ſmoothneſs, or greaſineſs, which the texture of the rubbed metal excites when abraded by the ſtone. When two ſtrokes perfectly alike in colour are made upon the ſtone, he may then wet them with aqua fortis, which will affect them very differently if they be not ſimilar compoſitions: or the ſtone itſelf may be made red-hot by the fire, or by the blow-pipe, if thin black pottery be uſed; in which caſe the phenomena of calcination will differ according to the nature and quantity of the alloy.

Aſſay of gold ores in the moiſt way.

Gold ores may be aſſayed in the moiſt way by pounding them very fine, weighing a determinate portion, and attempting their ſolution in nitrous acid, which will diſſolve the matrix if it conſiſt of calcareous earth; or, if it be ſelenite, the powder may be digeſted in aqua regia as long as any metallic ſubſtance is taken up; after which the gold may be precipitated by an addition of vitriol of iron, which will cauſe it to fall down in the metallic ſtate.

Uſes of gold.

The principal uſe of gold is as the medium of exchange in coin; for which it has been choſen to occupy the firſt place, on account of its ſcarcity, its great weight, and its not being ſubject to tarniſh. The gold coins of Great Britain contain eleven parts of gold, and one of copper.

Gold is likewiſe uſed in gilding; for which purpoſe, as we have already ſhewn, it is mechanically divided into leaves of extreme thinneſs. Theſe are ſtuck upon wood, previouſly ſmeared with adheſive oil, or animal

glue,

GOLD.
Water-gilding.

glue, called fize. The procefs called water-gilding, which is ufually applied to copper or brafs, is performed by immerfing the clean copper into a diluted folution of mercury. The copper is corroded by the acid, which at the fame time depofits a thin coating of mercury. This coating, after the piece is wafhed, facilitates the adhefion of an amalgam of gold, which is then to be rubbed upon it. The mercury is afterwards volatilized by heat; and the work is finifhed by burning gilding wax upon it, which is a compofition of red bole, verdigrife, alum, and bees wax. The intention of this laft application appears to be that of concealing the defects of the gilding.

There is another method of gilding, which is performed by fteeping linen rags in a folution of gold. Thefe are afterwards dried and burned to afhes, which contain gold in a very divided ftate. Nothing more is neceffary than to moiften the end of a cork, and dip it in this burned matter, together with a little wood-afhes, and rub it upon the face of the filver intended to be gilded. By this means the gold eafily adheres.

The other ufes of gold, in laces, &c. are fufficiently known.

CHAP. II.

CONCERNING SILVER.

SILVER. Characters of silver.

SILVER is the whiteſt of all metals, conſiderably harder than gold, very ductile and malleable, but leſs malleable than gold; for the continuity of its parts begins to break when it is hammered out into leaves of about the hundred and ſixty thouſandth of an inch thick, which is more than one third thicker than gold leaf: in this ſtate it does not tranſmit the light. Its ſpecific gravity is moderate, being inferior to platina, gold, mercury, and lead. It ignites before melting, and requires a ſtrong heat to fuſe it. The heat of common furnaces is inſufficient to calcine it: but the heat of the moſt powerful burning lenſes vitrifies a portion of it, and cauſes it to emit fumes; which, when received on a plate of gold, are found to be ſilver in the metallic ſtate. It has likewiſe been partly calcined by twenty ſucceſſive expoſures to the heat of the porcelain furnace at Sêves. The air alters it very little; though it is diſpoſed to obtain a thin purple or black coating from the ſulphureous vapours which are emitted from animal ſubſtances, drains, or putrefying matters. This coating, after a long ſeries of years, has been obſerved to ſcale off from images of ſilver expoſed in churches; and was found, on examination, to conſiſt of ſilver united with ſulphur.

Solubility of ſilver in acids.

Silver is ſoluble in the vitriolic acid when concentrated and boiling, and the metal in a ſtate of diviſion. The marine acid ſcarcely acts upon it, unleſs dephlogiſticated: but the nitrous acid diſſolves it with great rapidity, and with a plentiful diſengagement of nitrous air; which, during its extrication, gives a blue or green colour to the acid, that entirely diſappears if the ſilver made uſe of be pure: if it contain copper, the ſolution remains greeniſh; and if the acid contain either vitriolic or marine acid, theſe combine with a portion of the ſilver, and form ſcarcely ſoluble compounds, which fall to the bottom. If the ſilver contain gold, this metal ſeparates in blackiſh coloured flocks. The nitrous acid diſſolves more than half its weight of ſilver; and the ſolution is very cauſtic, that is to ſay, it deſtroys and corrodes animal ſubſtances very powerfully. This action appears to depend on the ſtrong diſpoſition of the ſilver to become revived; by which it either attracts phlogiſton from thoſe ſubſtances according to the ancient theory, or communicates vital air to them according to the new theory: ſo that the animal ſubſtances undergo a proceſs equivalent to combuſtion.

Combination with nitrous acid.

The ſolution of ſilver, when fully ſaturated, depoſits thin cryſtals as it cools, and alſo by evaporation. Theſe are called lunar nitre, or nitre of ſilver. A gentle heat is ſufficient to fuſe them, and drive off their water of cryſtallization. In this ſituation it is of a black colour, may be caſt into ſmall ſticks in a mould, and then forms the lapis infernalis, or lunar cauſtic, uſed in ſurgery. A ſtronger heat decompoſes

 lunar

SILVER.

lunar nitre, the acid flying off, and the filver remaining pure. It is obvious that, for the purpofe of forming the lunar cauftic, it is not neceffary to fuffer the falt to cryftallize, but that it may be made by evaporating the folution of filver at once to drynefs; and as foon as the falt is fufed, and ceafes to boil, it may be poured out. The nitrous acid driven off from lunar nitre is decompofed, the products being vital air and phlogifticated air.

Lunar cauftic.

Page 172, 173.

Although the nitrous acid diffolves filver with fuch great facility, it appears to do this only in confequence of its great power to calcine the metal; for the vitriolic and marine acids have a greater attraction for the calx. They accordingly take it from that acid, and form falts; which, as we have already obferved, fall to the bottom on account of their difficult folubility. The vitriol of filver, which is formed by pouring vitriolic acid into the nitrous folution of filver, is fparingly foluble in water, and on that account forms cryftals, which are fo fmall that they compofe a white powder. The marine acid precipitates from nitrous acid the faline compoud called luna cornea, or horn filver, which has been fo diftinguifhed becaufe, when melted and cooled, it forms a femi-tranfparent and partly flexible mafs, refembling horn. It is fuppofed that a preparation of this kind has given rife to the accounts of malleable glafs.

Vitriol of filver.

Lunea cornea.

Malleable glafs.

If any falt with bafe of alkali, containing the marine acid, be added to the nitrous folution of filver, the fame effect takes place by double affinity; the alkaline bafe uniting with the nitrous acid, and the filver falling down in combination with the marine acid.

Since

Since the marine acid throws down only ſilver, lead, and mercury, and the latter of theſe two are not preſent in ſilver that has paſſed cupellation, though a ſmall quantity of copper may elude the ſcorification in that proceſs, the ſilver which may be revived from luna cornea is purer than can readily be obtained by any other means. When this ſalt is expoſed to a low red heat, its acid is not expelled; and a greater heat cauſes the whole concrete either to riſe in fumes, or to paſs through the pores of the veſſel. To reduce it, therefore, it is neceſſary that it ſhould be triturated with its own weight of fixed alkali and a little water, and the whole afterwards expoſed to heat in a crucible whoſe bottom is covered with mineral alkali; the maſs of luna cornea being likewiſe covered with the ſame ſubſtance. In this way the acid will be ſeparated from the ſilver, which is reduced to its metallic ſtate.

SILVER.

Very pure ſilver obtained from luna cornea.

As the precipitate of luna cornea is very perceptible, the nitrous ſolution of ſilver is uſed as a teſt of the preſence of marine acid in waters; for a drop of this ſolution poured into ſuch waters will cauſe a very evident cloudineſs. The ſolution of ſilver is alſo uſed by aſſayers to purify the nitrous acid from any admixture of marine acid. In this ſtate they call it precipitated aqua fortis.

Teſt of marine acid in waters.

Purification of nitrous acid.

The precipitates of ſilver which are formed by the addition of alkalis or earths, are all reducible by mere heat, without the addition of any combuſtible ſubſtance. The fulminating combination of volatile alkali with ſilver, exhibits one of the moſt aſtoniſhing

Precipitates.

SILVER.

Preparation of fulminating silver.

instances of chemical detonation hitherto known*. Pure silver is dissolved in pale nitrous acid, and precipitated by the addition of lime-water. This calx, or precipitate, after decantation of the fluid, is to be dried by exposure to the air for three days. The inventor thinks the presence of light has some influence in the success of the experiment. The dried calx being agitated or stirred in a solution of caustic volatile alkali, assumes the form of a black powder, from which the fluid is to be decanted, and the black substance left to dry in the air. This is the fulminating silver.

Its effects.

Gunpowder and fulminating gold are not to be compared with this new product; as the former requires ignition, and the latter a sensible degree of heat, to cause them to fulminate. But the slightest agitation or friction is sufficient to cause the fulminating silver to explode. When it is once obtained, it can no more be touched. The falling of a few atoms of this preparation from a small height produced the detonation; a drop of water falling upon it had the same effect. No attempts therefore can be made to inclose it in a bottle; but it must remain in the capsule wherein, by evaporation, it obtained this terrible property.

Precautions.

To make this experiment with safety, it is proper to use no greater quantity than a grain of silver; the last deficcation should be made in a metallic vessel; and the face of the operator should be defended by

* Discovered by Berthollet. See the Journal de Physique for June 1788, p. 474.

a mask,

a mafk, with holes for the eyes defended with ftrong glafs.

Fulminating filver.

The volatile alkali made ufe of in converting the calx of filver into the black precipitate, was expofed to ebullition in a fmall matrafs of glafs; and the fluid being then fuffered to cool, the infide of the veffel became lined with fmall cryftals. When one of thefe was touched beneath the cold liquid, an explofion took place, which broke the matrafs in pieces, and threw the liquid up to the ceiling of the laboratory.

Theory of the inventor, page 231:

The inventor's theory of thefe effects is the fame as that of fulminating gold. The combination confifts of volatile alkali and calx of filver; that is to fay, in the new theory, of inflammable air, phlogifticated air, filver, and vital air. The flighteft change of temperature or agitation difpofes the inflammable air to combine with the vital air, which adheres very feebly to the filver. Thefe form water, while the phlogifticated air is difengaged, and the filver reduced to the metallic ftate. The explofion depends on the fudden tranfition of the phlogifticated air and the water to the elaftic ftate by heat: but the change of capacity from which the heat arifes has not yet been explained. On the phlogiftic theory, it will be faid that the filver is revived by combining with the inflammable air, or phlogifton of the alkali; while the phlogifticated and vital air fly off in the explofion.

—by the phlogiftic hypothefis.

Keir's compound acid, page 174.

It is a valuable difcovery of Mr. Keir *, that a mixture of ftrong vitriolic acid with the nitrous acid, or nitre, is a powerful folvent of filver, though it fcarcely

* Phil. Tranf. 1780, p. 367.

SILVER.

acts upon the other metals. This is of confiderable importance in the Birmingham manufactures, where the filver in the cuttings of plated copper is required to be feparated from this laft metal. For this purpofe the pieces of metal are put into a glazed earthen pan, and a compofition of eight or ten pounds of oil of vitriol, with one pound of nitre, is poured upon them, ftirred about, and the action of the fluid affifted by a heat between 100° and 200° of Fahrenheit. When the liquor is nearly faturated, the filver is to be precipitated by common falt, which may be eafily afterwards reduced; or, otherwife, the filver may be precipitated in its metallic ftate by adding to the folution a few of the pieces of copper, and a fufficient quantity of water, which enables the liquor to act on the copper. The theory of this effect ftill remains to be inveftigated.

Sulphur combines readily with filver in the dry way; but may be feparated by a ftronger heat. The fulphur of liver of fulphur likewife blackens filver, and combines with it, whether the filver be immerfed in the liquid folution, or expofed to hepatic air.

Action of aqua regia upon filver.

Aqua regia acts ftrongly on filver; but precipitates it in the form of luna cornea as faft as it is diffolved. This effect may be eafily underftood by confidering that the nitrous acid diffolves the filver, and the marine precipitates it.

The neutral falts alone do not alter filver either in the moift or dry way; nitre, in particular, does not deflagrate with this metal.

Precipitation of filver by metals.

Moft metallic fubftances precipitate filver in the metallic ftate from its folution. The affayers make ufe

ufe of copper to feparate the filver from the nitrous acid ufed in the procefs of parting. The precipitation of filver by mercury is very flow, and produces a peculiar fymmetrical arrangement, called the tree of Diana. In this, as in all precipitations, the peculiar form may be affected by a variety of concomitant circumftances; for which reafon one procefs ufually fucceeds better than another. Lemery directs that an ounce of fine filver be diffolved in a fufficient quantity of very pure and moderately ftrong nitrous acid; that this folution be mixed in a matrafs, or bottle, with about twenty ounces of diftilled water; and that, after the addition of two ounces of mercury, the whole be fuffered to repofe. During the fpace of forty days a kind of tree of filver will be formed on the furface of the mercury, with branches greatly refembling a vegetable fubftance in its ramifications. The foregoing procefs is faid by Macquer to fucceed very well; but the following, of Homberg, is much fhorter.

Tree of Diana.

Procefs of Lemery.

Make an amalgam, without heat, of four drams of leaf filver, with two drams of mercury. Diffolve this amalgam in four ounces, or a fufficient quantity of pure nitrous acid of a moderate ftrength; dilute this folution in about a pound and a half of diftilled water; agitate the mixture, and preferve it for ufe in a glafs bottle, with a ground ftopper. When this preparation is to be ufed, the quantity of one ounce is put into a phial, and the fize of a pea of an amalgam of gold or filver, as foft as butter, is to be added; after which the veffel muft be left at reft. Soon afterwards fmall filaments appear to iffue out of the ball

Homberg's procefs for making the tree of Diana.

SILVER. ball of amalgam, which quickly increaſe, and ſhoot out branches in the form of ſhrubs.

Theoretical obſervations. In the above experiment of Lemery the nitrous acid depoſits its ſilver at the ſame time that it takes up mercury; and in conſequence of the liquor being ſo much diluted, the proceſs goes on ſlowly, and the precipitated ſilver has time to arrange itſelf according to the law of its cryſtallization, whether that depend on the polarity of its particles, or on any other property not yet explained. In the method of Homberg there are two circumſtances which appear calculated to forward the proceſs: in the firſt place, the nitrous acid already contains mercury in ſolution, which may probably render it more diſpoſed to part with the ſilver; and, in the next place, the mercury is combined with ſilver or gold in the form of an amalgam. Theſe may perhaps facilitate the precipitation of the ſilver, by preſenting a baſe for it to combine with; which may be more perfectly at repoſe, becauſe leſs agitable than the fluid mercury in the former experiment. After all, however, though the general theory of the experiment is not difficult, yet it does not ſeem eaſy to point out the effectual cauſe of the differences between the two reſults.

Page 81.

Combinations of ſilver; with gold: Silver unites with gold by fuſion, and forms a pale alloy, as has been already mentioned in treating of that metal. —with platina. With platina it forms a hard mixture, rather yellower than ſilver itſelf, and of difficult fuſion. The two metals do not unite well. Silver melted with one tenth part of crude platina, from which the ferruginous particles had been ſeparated by a ſtrong magnet, could not be rendered clear

clear of fcabrous parts, though it was repeatedly fufed, poured out, and laminated between rollers. It was then fufed, and fuffered to cool in the crucible, but with no better fuccefs. After it had been formed, by rolling and hammering, into a fpoon for blow-pipe experiments, it was expofed to a low red heat, and became rough, and bliftered over its whole furface. The quantities were one hundred grains of filver, and ten grains of platina. Nitre was added during the fufions. SILVER.

Silver very readily combines with mercury. A very fenfible degree of heat is produced when filver leaf and mercury are kneaded together in the palm of the hand. With lead it forms a foft mafs, lefs fonorous than pure filver. With copper it becomes harder and more fonorous, at the fame time that it remains fufficiently ductile. This mixture is ufed in the Britifh coinage. Fifteen parts of filver, alloyed with one of copper, form the compound called ftandard filver. The mixture of filver and iron has been little examined. With tin it forms a compound which, like that of gold with the fame metal, has been faid to be brittle, however fmall the proportion; though there is probably as little foundation for the affertion in the one cafe as in the other. With bifmuth, arfenic, zinc, and antimony, it forms brittle compounds. It does not unite with nickel. The compound of filver and wolfram in the proportion of two of the former to one of the latter, was extended under the hammer during a few ftrokes; but afterwards fplit in pieces.

Combinations of filver with mercury:

—with lead:

—with copper:

—with tin, &c.

Silver

SILVER.

Native filver and its ores.

Silver is found either native or mineralized. The native filver is found in Peru, and various parts of Europe; fometimes in confiderable maffes, and often diffufed through fand, ochre, or lime-ftone. It is feldom pure, but is generally alloyed with copper, and fometimes with gold, iron, or regulus of antimony. The mineralized filver contains fulphur and arfenic, or both, with other admixtures.

Purifying of native filver.

Native filver may be purified by pounding or wafhing, or amalgamation with mercury; and the filver itfelf is refined by cupellation with lead in the fame manner as gold. In the large way, the litharge, or vitrified lead, is blown from the furface of the filver by bellows, inftead of foaking into the crucible. Gold may be feparated from filver by parting with aqua regia, or treatment with fulphur in the dry way, which combines with the filver, and leaves the gold difengaged.

Vitreous ore of filver.

The vitreous filver ore is the richeft ore of filver, and contains from feventy to eighty pounds of filver in the hundred weight; the reft being fulphur, with rarely any other metal, except a fmall portion of iron. It is found either in folid large lumps, or inherent in quartz or fpar. Its colour generally refembles that of lead; but grows dark by expofure to the air. It ufually poffeffes a flight degree of malleability, and is fufficiently foft to be cut by a knife.

Analyfis in the moift way:

To analyfe this ore in the moift way, it may be boiled in nitrous acid, which acidifies the fulphur, and caufes great part to fly off in the form of vitriolic acid air. Common falt, or marine acid, will precipitate

SILVER.

pitate the ſilver in the form of luna cornea, which may be either reduced or accounted for by deducting one fourth of its weight when waſhed and dried, which fourth of its weight is marine acid.

—in the dry way.

In the dry way, it may be reduced by expoſing it to a heat not ſufficient to melt it. In this way the ſulphur is diſſipated, and the ſilver remains uſually in a fibrous form. Small portions may be conveniently decompoſed in this manner by the blow-pipe upon charcoal.

Red ſilver ore.

The red ſilver ore is a heavy ſhining ſubſtance, either tranſparent or opake; ſometimes grey or blackiſh, but always reddiſh when powdered: it uſually contains more than half, and ſometimes three fourths of its weight of ſilver, the reſt being arſenic and ſulphur.

Analyſis in the moiſt way.

In the moiſt way, this ore is analyſed by reducing it to fine powder, and boiling it with diluted nitrous acid. The reſidue, which contains the ſulphur and the arſenic, muſt be edulcorated with water; and the arſenic may be diſſolved by boiling in a ſufficient quantity of aqua regia. If the ſulphur ſhould retain any luna cornea, it may be ſeparated by keeping it for ſome days in a cloſed veſſel, with its own weight of diluted cauſtic volatile alkali. The clear nitrous ſolution being mixed with the water uſed in the edulcoration, affords a precipitate of luna cornea by the addition of ſea ſalt, which may either be reduced or accounted for in the ſame manner as in the aſſay of the vitreous ſilver ore.

White ore of ſilver analyſed.

Silver united with ſulphur, arſenic, and copper, is generally called the white ore of ſilver. One hundred grains of this being reduced to a powder, and gently boiled

SILVER.

boiled for an hour in more than twelve times its weight of diluted nitrous acid, the copper and silver are dissolved, and a white residuum remains. The silver is precipitated in the metallic form by the immersion of a clean plate of copper; and the copper being afterwards precipitated by the addition of volatile alkali, may be accounted for by allowing 194 grains of the precipitate to one hundred of the copper, and deducting the loss sustained by the plate of copper which was immersed in the solution. The white residuum may be deprived of its arsenic and iron by boiling in marine acid. The arsenic may be precipitated by the addition of wat.r; and afterwards the iron, if any, by Prussian alkali. The undissolved sulphur may be treated with volatile alkali, to try whether it contains either copper or luna cornea.

The other ores of silver, of which there is considerable variety, may be analysed by varying the processes according to the supposed or known general contents of the ore*.

Method of assaying silver, or its ores, in the dry way.

Sulphureous and arsenical silver ores may be assayed by roasting and subsequent fusion with a greater or less quantity of flux. In the fusion, the silver is obtained alloyed with lead, copper, or iron, which may be separated by cupellation with lead, and the silver left pure. The fineness of silver is denoted by the assayers, by mentioning the number of pennyweights and grains of pure silver contained in the ounce. So

See page 237.

* For which consult Bergman's Treatise on the Art of Assaying in the Humid Way, inserted in the 2d vol. of the English translation of his Opuscula, or Essays.

that

that if an ounce of ſilver be found to loſe half a pennyweight by cupellation, it is ſaid to be eleven pennyweights twelve grains fine; if it loſe a whole pennyweight, it is ſaid to be eleven pennyweights fine, &c. Silver is likewiſe tried by the touch, in the ſame manner as gold. For this purpoſe, the aſſayers are provided with a ſet of needles or ſmall bars; the firſt of which contains $\frac{1}{16}$ part of its weight of copper, and the reſt ſilver; the ſecond contains $\frac{2}{16}$ parts of copper; the third $\frac{3}{16}$ parts; and ſo on to the laſt, which contains 15 parts of copper to one of ſilver. By the reſemblance of colour on the touchſtone, an eſtimate may be made of the fineneſs of the ſilver to ſomething nearer than the 30th part of the whole, which is a conſiderable acquiſition in the examination of ſmall articles, ſuch as rings, tr[illegible] and the like. It is true indeed that the uſe of the touch ſuppoſes the precious metal to be alloyed with copper only, which may not be the caſe; and conſequently the aſſayer is liable to be deceived in this reſpect: but he may in this caſe have recourſe to aqua fortis, or the blow-pipe, in the ſame manner as directed in the foregoing chapter.

Page 239, 240.
Aſſay of ſilver by the touch.

In the large works, where ſilver is extracted, the proceſſes are grounded on the properties already deſcribed. Native ſilver is triturated with mercury; after which the amalgam is waſhed, to ſeparate the earthy particles; and the quickſilver ſeparated, partly by preſſure in leathern bags, and partly by diſtillation in iron retorts.

Extraction of ſilver from ores in the large way, by amalgamation:

Rich ſulphureous ores are roaſted, and fuſed with lead, to refine the ſilver by cupellation. The poorer ores,

—by fire.

SILVER. ores, which contain copper, are fufed with pyrites, which affords a mafs confifting of copper, fulphur, and filver. Lead is then added, and the mafs treated in the way of eliquation. The lead flows out, carrying the filver with it; and, laftly, thefe two metals are feparated by the teft, on which the lead is converted into litharge, and the filver remains pure.

Ufes of filver. The ufes of filver are well known: it is chiefly applied to the forming of various utenfils for domeftic ufe, and as the medium of exchange in money. Its difpofition to affume a black colour by tarnifhing, and its foftnefs, appear to be the chief objection to its ufe in the conftruction of graduated inftruments for aftronomical and other purpofes, in which a good white metal would be a defirable acquifition.

CHAP.

CHAP. III.

CONCERNING PLATINA.

PLATINA. Characters of platina.

PLATINA is one of the metals for the difcovery of which we are indebted to our cotemporaries. It has yet been found only in Spanifh America, among the gold mines there. We receive it in the form of fmall particles, from the minuteft fize up to that of a pea; though thefe laft are very feldom met with. Its particles or grains are fmooth, irregularly figured with round edges, and are flattened, probably by hammering in the mills in which the gold is amalgamated. Thefe grains are of a whiter colour than iron, and are confiderably malleable. In the ftate in which we receive them, they are often mixed with ferruginous fand, which may be feparated by the magnet; and alfo with grains of quartz or cryftal. When it is feparated from heterogeneous particles, the crude platina itfelf is flightly magnetic, and is between fixteen and eighteen times as heavy as water. The moft violent fires are infufficient to melt it, though its parts may be made to cohere together into a folid button by the ftrong heat of a wind furnace. Burning lenfes of the moft powerful kind fufe it, and convert it into a malleable metal; and fmall portions of crude platina may be eafily melted upon charcoal, by flame urged by a ftream of vital air.

Crude platina.

Pure platina.

Pure or refined platina is by much the heavieft body in nature. It is very malleable, though confi-

PLATINA.

Characters of platina.

derably harder than either gold or ſilver; and it hardens much under the hammer. Its colour on the touchſtone is not diſtinguiſhable from that of ſilver. When in the higheſt degree of purity, it is not magnetical; but when its ſpecific gravity is as low as 21.36 it contains iron ſufficient to render it magnetical. Pure platina requires a very ſtrong heat to melt it; but when urged by a white heat, it is ſaid that its parts will adhere together by hammering. This property, which in iron is diſtinguiſhed by the name of welding, is peculiar only to platina and that metal, which reſemble each other likewiſe in their infuſibility.

Welding.

Solution in dephlogiſticated marine acid:

Platina is not altered by expoſure to air; neither is it acted upon by the moſt concentrated ſimple acids, even when boiling, or diſtilled from it. The dephlogiſticated or aërated marine acid diſſolves it, as does likewiſe aqua regia; and both are ſaid to form the ſame ſalts with it. In this particular of ſolubility platina reſembles gold.

—in aqua regia.

The aqua regia beſt adapted to the ſolution of platina is compoſed of equal parts of the nitrous and marine acids. The ſolution does not take place with rapidity. A ſmall quantity of nitrous air is diſengaged; the colour of the fluid becoming firſt yellow, and afterwards of a deep reddiſh brown, which, upon dilution with water, is found to be an intenſe yellow. This ſolution is very corroſive, and tinges animal matters of a blackiſh brown colour: it affords cryſtals by evaporation. The metal is precipitable from its ſolution by ſal ammoniac; a property by which it is diſtinguiſhed from all other metals, in the ſame manner

Diſtinctive character.

manner as the ſolution of gold is characterized by its precipitation upon the addition of martial vitriol. In this way, a compound ſolution of gold and platina may be ſeparated by precipitating either of the two metals at pleaſure. The orange-coloured precipitate of platina, obtained by means of ſal ammoniac, is a ſaline ſubſtance, completely ſoluble in water; but its component parts have not been well aſcertained. It is fuſible without addition by a good forge furnace, and forms a brilliant, denſe, and cloſe-grained button, which is not malleable, probably on account of part of the ſaline ſubſtance not being diſſipated.

Separation of gold from platina.

The ſame precipitate, expoſed to the ſtronger heat of a blaſt furnace, was fuſed into a perfectly malleable regulus by the Count de Milly. See Magellan's Cronſtedt, page 574.—I have ſeveral ſmall ſpecimens of this platina, which is in thin plates or bars; their ſpecific gravity is above $21\frac{1}{2}$; in which I do not pretend to a greater accuracy than $\frac{1}{200}$th part of the weight, becauſe the quantities are ſo ſmall. It is perfectly malleable, hard, and elaſtic, and obeys a ſtrong magnet when the pieces are floated upon water. One ſmall piece which was fuſed by Parker's lens is not at all magnetical, and ſeems to exceed 22 in ſpecific gravity.

Malleable platina.

Alkalis and the ſoluble earths precipitate platina in the form of a calx from its ſolution. The Pruſſian alkali, hereafter to be deſcribed, does not precipitate it as it does all other metals; but it throws down a plentiful blue precipitate, conſiſting of iron, which was contained in the Pruſſian blue. This property therefore affords a method of ſeparating the iron

Precipitates.

PLATINA.

from platina, which always contains it. The volatile alkali precipitates platina of an orange yellow colour. Neutral falts, with bafe of fixed alkali, do not precipitate it.

Moft of the metals precipitate platina from its folution; but it does not in general fall down in the metallic ftate.

Crucibles of platina.

This metal is fcarcely affected in the dry way by faline fubftances. Calx of arfenic facilitates its fufion, and the femi-metal forms a brittle compound with the platina. Mr. Achard fucceeded in making crucibles of platina, by fufing equal parts of platina, white arfenic, and vegetable alkali. This matter, when cooled, was reduced to a powder, and rammed into the mould of the veffel intended to be formed. A ftrong heat, quickly raifed, and continued for fome time, fufed the mafs; and, after diffipating the arfenic and the alkali, left the platina in the form defired.

Combinations with metals.

Platina does not readily combine with gold, except by a ftrong heat; and it greatly debafes the colour of that metal: it does not readily unite with filver; to which however it communicates part of its hardnefs, while it impairs its colour and brilliancy. It altogether refifts the action of mercury; or at leaft this mutual action does not feem to be ftronger than that of mercury and iron. Lead and platina unite very well by fufion; the lead becomes much lefs ductile, and even brittle, according to the proportions of the platina. In the attempts to cupel platina with lead, the procefs went on as it does ufually with filver and gold in the beginning; but as foon as a confiderable portion of the lead was diffipated, the platina fixed, and the operation ceafed.

Cupellation.

PLATINA. Combinations with metals.

ceafed. But with a ftronger heat, fuch as that of a porcelain furnace, the operation may be completed, and malleable platina obtained free from lead. It has not been united with forged iron; but with caft iron it formed a brittle compound. With copper it melts with confiderable facility; and in due proportions forms a compound which takes a very beautiful polifh, and is not fubject to tarnifh: this has been ufed for the mirrors of reflecting telefcopes. Tin and platina melt very eafily, and form a compound, fcarcely ductile when the tin abounds, but very brittle when the platina predominates. Bifmuth and antimony unite with platina by fufion, and form brittle compounds, which do not promife to be of any confiderable utility. Zinc likewife combines readily with it, and renders it very fufible; this alloy is brittle, hard, and of a blueifh colour. Wolfram can fcarcely be brought to fhew any fign of union with platina. Cobalt, manganefe, and molybdena have not been tried.

The commerce of platina has been interdicted by the Spanifh miniftry, from an apprehenfion that it might be employed in the adulteration of gold.— Whether this prohibition has fince been taken off, I know not; but it feems needlefs, as the mixture of platina greatly alters the obvious qualities of gold, and can be very readily afcertained by the teft of fal ammoniac before pointed out.

 CHAP.

CHAP. IV.

CONCERNING MERCURY.

MERCURY. Characters of mercury.

MERCURY is diftinguifhed from all other metals by its extreme fufibility, which is fuch that it does not take the folid ftate until cooled to the thirty-ninth degree below o on Fahrenheit's thermometer; and of courfe it is always fluid in the temperate climates of the earth. Its colour is white, and rather bluer than filver. In the folid ftate it is malleable*; its fpecific gravity is greater than that of any of the other metals, platina, gold, and wolfram excepted. It is volatile, and rifes in fmall portions at the common temperature of the atmofphere, as is evinced by feveral experiments, more efpecially in a vacuum, fuch as obtains in the upper part of a barometer tube. At the temperature of about fix hundred degrees it boils rapidly, and rifes copioufly in fumes. Few of the other metals melt at fo low a temperature as the boiling point of mercury. When expofed to fuch a heat as may caufe it to rife quickly in the vaporous form, it gradually becomes converted into a red calx, provided vital air be prefent. This is known by the name of precipitate per fe. A greater heat however revives this metallic calx, at the fame time that the vital air is again extricated.

Precipitate per fe.

* The reader will find an ample account of the freezing of quickfilver in Dr. Blagden's Hiftory, vol. lxxiii. of the Philofophical Tranfactions.

Mercury

MERCURY. Characters.

Mercury is not perceptibly altered by expofure to the air; though by long agitation, with accefs of air, it becomes converted into a black powder or calx, which gives out vital air by heat, the metal being at the fame time revived. This metal is difpofed to attract moifture; and cannot, for that reafon, be ufed in the conftruction of the beft barometers and thermometers until it has been firft boiled in an open veffel for the fpace of about half an hour.

Electric light.

When mercury is agitated in a dry glafs bottle, the friction between the metal and the glafs produces electricity. If the bottle be imperfectly exhaufted, this electricity paffes into the vacuum, and produces a light which was formerly thought to be a proof of the perfection of the vacuum in the upper part of barometer tubes; but which in fact does not appear in fuch barometers as have been cleared of air by careful boiling in the tube.

Action of vitriolic acid on mercury.

The vitriolic acid does not act on this metal, unlefs it be well concentrated and boiling. For this purpofe, mercury is poured into a glafs retort, with near twice its weight of vitriolic acid. As foon as the mixture is heated, a ftrong effervefcence takes place, vitriolic acid air efcapes, the furface of the mercury becomes white, and a white powder is produced; when the vitriolic air ceafes to come over, the mercury is found to be converted into a white, opake, cauftic, faline mafs, at the bottom of the retort, which weighs one third more than the mercury, and is decompofed by heat. Its fixity is confiderably greater than that of mercury itfelf. If the heat be raifed, it gives out a confiderable

MERCURY. quantity of vital air, the mercury being at the fame time revived.

Vitriol and calx of mercury. The white mafs produced by the action of vitriolic acid upon mercury, confifts partly of a faline mafs, or vitriol of mercury, and partly of a calx, or mercury united to vital air (fimply, according to the new theory; or deprived of phlogifton, according to the old theory, which phlogifton is fuppofed to enter into the combination of the vitriolic acid air). Water feparates the falt from the calx, which laft is then of a yellow colour. Much wafhing is required to produce this colour, if cold water be ufed; but if a large quantity of hot water be poured on, the calx immediately affumes a bright lemon colour. In this ftate, it is called turbith mineral.

Turbith mineral.

The vitriol of mercury affords a falt by evaporation, in fmall needle-formed deliquefcent cryftals. The addition of a large quantity of water, more efpecially if heated, decompofes vitriol of mercury, which depofits turbith mineral, unlefs there be an excefs of acid in the fluid.

Precipitates.

The fixed alkalis, magnefia, and lime, precipitate mercury from its folution: thefe precipitates are reducible in clofed veffels by mere heat without addition.

Solution in nitrous acid. The nitrous acid rapidly attacks and diffolves mercury, at the fame time that a large quantity of nitrous air is difengaged; and the colour of the acid becomes green during its efcape. Strong nitrous acid takes up its own weight of mercury in the cold; and this folution will bear to be diluted with water. But if the folution be made with the affiftance of heat, a much larger

larger quantity is diſſolved; and a precipitate of calx will be afforded by the addition of diſtilled water, which is of a yellow colour if the water be hot, or white if it be cold, and greatly reſembles the turbith mineral produced with vitriolic acid: it has accordingly been called nitrous turbith. If acid be added to the ſolution made with heat, it loſes its property of being decompoſed by water. This decompoſition is not complete, but only deprives the acid of the redundant calx.

Nitrous turbith.

All the combinations of mercury and nitrous acid are very cauſtic, and form a deep purple or black ſpot upon the ſkin. They afford cryſtals, which differ according to the ſtate of the ſolution. When nitrous acid has taken up as much mercury as it can diſſolve by heat, it uſually aſſumes the form of a white ſaline maſs. When the combination of nitrous acid and mercury is expoſed to a gradual and long continued low heat, it gives out a portion of nitrous acid, and becomes converted into a red ſubſtance, ſimilar in all reſpects to the red calx of mercury formed by ſimply heating it in contact with vital air. This is known by the name of red precipitate.

Mercurial nitre.

Red precipitate:

When red precipitate is ſtrongly heated, a large quantity of vital air is diſengaged, together with ſome phlogiſticated air, and the mercury is ſublimed in the metallic form.

—decompoſed.

Mercurial nitre is more ſoluble in hot than cold water, and affords cryſtals by cooling. It is decompoſed by the affuſion of a large quantity of water, unleſs the acid be in exceſs.

When mercury is diſſolved in nitrous acid by means of

MERCURY.

Nitrous solution.

of heat, nitrous air is emitted at first; and afterwards it ceases, though the solution still proceeds. The mercury which is taken up during the first part of the process is calcined, and the other portion is dissolved in the metallic state. If the solution be stopped in the first part of the process, fixed and volatile pure alkalis precipitate the yellow calx; but if the solution be continued after the escape of the elastic fluid has ceased, the precipitate obtained by the same means is black, on account of the admixture of metallic mercury, which may be separated from the yellow calx by distillation.

Precipitates.

Ponderous earth, magnesia, and lime, precipitate the nitrous solutions of mercury; and these precipitates, as well as all the other calces of this metal, are reducible by heat alone without addition.

Explosion of mercurial precipitates.

The precipitates of mercury from acids, by means of alkalis, possess the property of exploding when exposed to a gradual heat in an iron spoon, after having been previously triturated with $\frac{1}{6}$ of their weight of flowers of sulphur. The residue consists of a violet-coloured powder, which is converted by sublimation into cinnabar. It seems therefore as if the sulphur combined suddenly with the mercury, and expelled vital air in the elastic state.

Decomposition of the nitrous solution by other acids.

The vitriolic acid, or the salts containing it, decompose the nitrous solutions of mercury by virtue of the stronger attraction of the vitriolic acid to the metal. The precipitate which falls down does not essentially differ from the substance produced by the direct solution of mercury in the vitriolic acid. The marine acid likewise seizes the mercury dissolved in the nitrous acid,

and

and forms a compound which falls to the bottom. This consists of a very caustic salt, which is called corrosive sublimate, and is produced when the nitrous solution contains only calx of mercury; but when that solution is saturated with metallic mercury, the compound which falls down by the addition of marine acid is called white precipitate, and does not differ from the preparation which, when made in the dry way, is called calomel, or mercurius dulcis.

Corrosive sublimate.

Calomel.

The acetous and most other acids combine with the calx of mercury, and precipitate it from its solution in the nitrous acid.

The marine acid does not act perceptibly upon mercury in the metallic state; but the dephlogisticated or aërated marine acid readily dissolves it, and forms the same combination as arises from the direct union of marine acid with calx of mercury; that is to say, corrosive sublimate.

Combination of mercury with dephlogisticated marine acid.

The great specific gravity of mercury rendered it an object of peculiar attention to the alchemists and earlier chemists; many of whom hoped to fix it in the form of a solid substance, or to extract gold from it. From these motives, a great variety of processes have been made with it, by methods which are much less direct and simple than those of modern chemistry. Among others, the combination of the calx of mercury with marine acid is produced by several methods in the dry way by sublimation. In the large way, corrosive sublimate is prepared by triturating equal parts of mercury, common salt, and vitriol together, and exposing the whole to a moderate heat. The corrosive sublimate rises, and adheres to the upper part of the glass

Preparation of corrosive sublimate.

vessel.

MERCURY.

Corrofive fublimate.

veffel. In this operation, the vitriolic acid from the vitriol is fuppofed to calcine the mercury, or to dephlogifticate the marine acid of the common falt; in either of which cafes the compound of marine acid with calx of mercury will be formed. From this theory, it will eafily be underftood that corrofive fublimate may be prepared by various methods. If the white mafs or calx of mercury, produced by expofing that metal to the action of vitriolic acid, be heated in a matrafs with an equal quantity of common falt, this fublimate will be had by double affinity; the vitriolic acid partly faturating the alkali, and the marine acid uniting with the calx of mercury, and rifing by fublimation. In the fame manner, the nitrous mercurial falt, or the mercurial precipitates, may be ufed inftead of the calx of mercury by vitriolic acid.

Caufticity of metallic falts.

As the caufticity of metallic falts depends chiefly on the difpofition of the calcined metal to refume the metallic ftate, at the fame time that it burns or calcines the fubftance to which it may be applied; it is accordingly found that corrofive fublimate poffeffes this property in the moft eminent degree; it is therefore one of the moft active mineral poifons. This falt is foluble in water, though fparingly, and alfo in ardent fpirit. It is precipitated of an orange colour by fixed alkalis. The abforbent earths likewife throw down its calx. Volatile alkali affords a white precipitate, which foon after affumes a flate colour.

Sal alembroth.

Corrofive fublimate becomes much more foluble in water by the addition of fal ammoniac, with which it forms a triple compound, called fal alembroth by the alchemifts, which cryftallizes by cooling. The addition

addition of a fixed alkali throws down a white calx of mercury, called white precipitate in the difpenfatories.

MERCURY.

White precipitate.

Preparation of calomel, or mercurius dulcis.

The preparation of calomel is ufually made by triturating corrofive fublimate in a glafs mortar with fluid mercury, added by a little at a time, until no more can be made to difappear. A fmall quantity of water added to the corrofive fublimate during this part of the procefs, prevents that falt from rifing in the form of noxious duft. In this ftate, the combination is the fame a that obtained from the faturated nitrous folution of mercury by the addition of marine acid. The mixture of corrofive fublimate and mercury is more perfectly combined by expofing it to fublimation. It adheres to the internal part of the fubliming veffel in the form of a white mafs, of a ftriated texture. If there be any fufpicion of its containing corrofive fublimate, which is not probable on account of the more volatile nature of the latter, they may be feparated by means of warm water, the calomel being infoluble.

Butter of antimony.

When one part of antimony, which is the native combination or ore of antimony with fulphur, is triturated or accurately mixed with two parts of corrofive fublimate, and expofed to diftillation, the dephlogifticated or aërated marine acid combines with the regulus of antimony, and rifes in the form of the compound called butter of antimony; while the fulphur combines with the mercury, and forms cinnabar. If the regulus of antimony be ufed inftead of the mineral, the refidue which rifes laft confifts of running mercury, inftead of cinnabar.

The

MERCURY. Cinnabar.

The combination of mercury and ſulphur is called cinnabar. It is one of the moſt uſual ores of this metal. Native cinnabar is not much uſed; but the artificial combination of the ſame nature is well known in the arts by the name of vermilion. The manufacture of this pigment has long been in the hands of the Hollanders, who kept it a ſecret; and as there is ſome difficulty in perfectly ſucceeding in the proceſs, chemical writers have given various methods of performing it, moſt of which, according to Mr. Tuckert, are inaccurate. This gentleman has given a full account of the method uſed at Amſterdam, which I find extracted from Crell's Chemical Journal, and inſerted in the fourth volume of the Annales de Chimie. Its contents are as follow:

The manufactory at which Mr. Tuckert ſeveral times aſſiſted in the preparation of artificial cinnabar is without the Utrecht port at Amſterdam; and is one of the moſt conſiderable in Holland. Forty-eight thouſand pounds of vermilion are annually made in three furnaces, by four workmen, beſides other mercurial preparations.

The ethiops mineral is firſt prepared by mixing together 150 pounds of ſulphur with 1080 pounds of pure mercury, and then expoſing the mixture to a moderate heat in a flat-bottomed poliſhed iron veſſel, one foot in depth, and two feet and a half in diameter. Its form is that of a chocolate machine. Mr. Tuckert does not enter into the particular manipulations of the Hollanders in this part of the proceſs, becauſe the methods of producing the black combination of mercury with ſulphur are well known.

2 The

Cinnabar.

The mercurial ethiops thus prepared is in the next place pounded, in order that it may more readily be put into fmall earthen bottles, capable of holding each about 24 ounces of water. Thirty or forty of thefe bottles are filled, to be in readinefs for the fubfequent operation.

In the next place, three large pots or fublimatory veffels made of clay and very pure fand are taken. Thefe veffels are previoufly covered with a coating of lute, which is fuffered to become perfectly folid and dry before the veffel is ufed. Mr. Tuckert refers to a German tranflation of a work of Mr. Machy for the figure of thefe veffels, as well as for the compofition of the lute. As we have not that tranflation, it is impoffible for us to give any further information on thefe heads than may be gathered from the reft of this memoir. Thefe pots are placed over three furnaces upon iron circles. The fublimatory veffels may be of different fizes, and the furnaces are conftructed in fuch a manner as that the flame circulates freely round the veffels, to two thirds of their height.

When the veffels are duly placed in their furnaces, a moderate fire is firft lighted, which is gradually raifed until they become red hot. The fuel is turf, or rather peat, commonly ufed throughout the United Provinces. As foon as the veffels are red hot, a bottle of the ethiops is poured into the firft, another into the fecond, and another into the third. In the fubfequent progrefs of the operation, two, three, and perhaps more bottles may be poured in at a time; but this depends on the ftrength of the in-

flammation

MERCURY. Cinnabar.

flammation exhibited by the ethiops after its introduction; the flame of which fometimes rifes to the height of four and even fix feet. When this is a little diminifhed, the mouth of the veffel is covered with a plate of iron, one foot fquare and an inch and a half thick, which perfectly clofes it. In this way, during thirty-four hours, the whole of the prepared matter is introduced into the three pots, that is to fay, for each pot three hundred and fixty pounds of mercury, and fifty of fulphur.

After all the ethiops has been introduced, the fire is duly kept up; and when the whole fublimation has taken place, it is fuffered to go out, which requires thirty-fix hours from firft to laft. The workmen know when the fire is too ftrong or too weak, by the appearance of the flame when the iron cover is taken off: if too ftrong, the flame rifes to the height of feveral feet; if on the contrary it be too weak, the flame barely appears—playing about the edges of the pot. The proper degree of heat is, when upon taking off the cover a brifk flame appears, but does not rife more than three or four inches above the opening.

In the laft thirty-fix hours, the mafs was ftirred every quarter or half hour with an iron bar, to accelerate the fublimation. The workmen do this with fo much courage, that Mr. Tuckert was every time apprehenfive they would fall into the veffels.

When the whole is cool, the veffels are taken out by means of iron circles, which prevent their breaking. The cinnabar is taken out by breaking the

veffel.

veffel. Each veffel conftantly affords four hundred pounds of cinnabar, the lofs of original weight in each being ten pounds.

MERCURY.

Cinnabar.

The cinnabar does not attach itfelf to the plates of iron, becaufe they are fo frequently taken off, excepting towards the end, when the veffels were left untouched. Thefe plates are not in the leaft corroded.

Livers of fulphur are decompofed in the humid way by mercury, which unites with the fulphur. With the fixed alkaline livers of fulphur it forms a black powder, or ethiops, by agitation, which in the courfe of a number of years becomes red; but the volatile alkaline hepar, or fuming liquor of Boyle, converts mercury into a fine cinnabar in a very fhort time. Turbith mineral, and the precipitates of mercury, are likewife converted into cinnabar by this alkaline hepar.

Cinnabar formed in the humid way.

Mercury unites by trituration with oils and mucilages, with which it forms black or deep blue compounds. A fmall part of the mercury in thefe feems to be in combination, and the reft in a ftate of extreme divifion.

Unguents, &c.

This metal can fcarcely be exhibited in the dry way, on account of its volatility. The degree of heat required to convert it into the red calx called precipitate per fe, is rather lower than its boiling point, and a greater reduces it again to the metallic ftate. The calcination and reduction of mercury, without addition, afford one of the ftrongeft arguments in favour of the fyftem which rejects phlogifton.

Page 262.

In the production of the red calx of mercury, it is required that air be prefent, and the metal kept in a ftate

Red calx of mercury, or precipitate per fe.

MERCURY.

Precipitate per ſe.

ſtate of briſk evaporation. On this account it is found convenient that the veſſel ſhould be ſo deep, and its aperture ſo ſmall, that the fumes may not make their eſcape. It may be inferred that, in this as well as other calcinations, there is an abſorption of vital air; more eſpecially as vital air is expelled from the calx by heat *. When the experiment is made in cloſed veſſels by means of a body of the kind marked C, fig. 15, whoſe neck is introduced beneath a jar containing common air over mercury, the vital part is abſorbed, and phlogiſticated or foul air remains; and afterwards, by an augmentation of heat, the mercury is revived, at the ſame time that it reſtores the conſtitution of the air by the emiſſion of the vital air. Ten days or a fortnight's conſtant heat is required to convert a few grains of mercury into precipitate per ſe in the ſmall way.

Amalgams.

Mercury, being habitually fluid, very readily combines with moſt of the metals, to which it communicates more or leſs of its fuſibility. When theſe metallic mixtures contain a ſufficient quantity of mercury to render them ſoft at a mean temperature, they are called amalgams.

Combinations of metals.

It very readily combines with gold, ſilver, lead, tin, biſmuth, and zinc; more difficultly with copper, arſenic, and regulus of antimony; and ſcarcely at all with platina or iron: it does not unite with nickel or cobalt; and its action on mangeneſe, wolfram, and molybdena is not known. Looking-glaſſes are covered on the back ſurface with an amalgam of tin.

* Lavoiſier, Traité Elémentaire de Chimie, page 35.

In

In this operation, mercury is poured on tin foil, upon a flat ſtone, and ſpread with a feather till its union with the tin has brightened every part of its ſurface. A large quantity of mercury is then poured on, and the glaſs is ſlided along the fluid ſurface; upon which it is afterwards preſſed by weights, to exclude the ſuperfluous mercury.

MERCURY. Combinations of metals.

Mercury is found native in ſlaty or quartzoſe earths, or viſibly diffuſed through maſſes of clay or ſtone. Native precipitate per ſe, or calx of mercury, has alſo been found; and this metal has likewiſe been met with in combination with the vitriolic and marine acids. Its volatility may probably have cauſed it to be overlooked in many minerals that may contain it. The greateſt quantity of mercury is found in combination with ſulphur, in the form of cinnabar. Mercury is a ſcarce metal. Moſt of the mercury in commerce is afforded by the mines of Idria in the Auſtrian dominions, Almaden in Spain, and Guancavelica in Peru. The native mercury requires little more than waſhing to ſeparate it from its matrix. Cinnabar in the native ſtate is frequently mixed with calcareous earth; in which caſe the mercury may be ſeparated by diſtillation, becauſe the calcareous earth combines with and detains the ſulphur. Pure cinnabar may be decompoſed by the addition of about one third of its weight of iron. In all caſes wherein pure mercury is required, it muſt be diſtilled from cinnabar, or its ſulphureous combination. For this purpoſe, the mercury may be converted into ethiops, and diſtilled with twice its weight of quicklime or iron filings. Mercury in commerce is judged to be pure, when it is perfectly

Native mercury and its ores.

Decompoſition of cinnabar.

Purity of mercury.

 fluid,

MERCURY.

fluid, and runs in neat globules, without any pellicle on its furface, or without foiling a funnel of clean white paper, through which it may be poured by a very fmall aperture at bottom. If it leaves nothing behind after evaporation, its purity may be ftill more depended upon.

Humid analyfis of cinnabar.

To analyfe native cinnabar, its ftony matrix fhould firft be diffolved in nitrous acid; and the cinnabar, being difengaged, fhould be boiled in eight or ten times its weight of aqua regia, compofed of three parts nitrous, and one marine acid: the mercury may then be precipitated in the metallic form by the addition of zinc.

Ufes of mercury.

The ufes of mercury have already been mentioned in the prefent chapter, and elfewhere. The amalgamation of the noble metals, water-gilding, the making of vermilion, the filvering of looking-glaffes, and the preparation of feveral powerful medicines, are the principal ufes to which this metal is applied.

CHAP. V.

CONCERNING LEAD.

LEAD is a white metal, of a confiderably blue tinge, very foft and flexible, not very tenacious, and confequently incapable of being drawn into fine wire, though it is eafily extended into thin plates under the hammer. Its weight is very confiderable, being rather greater than that of filver. Long before ignition, namely, at about the 540th degree of Fahrenheit's thermometer, it melts; and then begins to be calcined, if refpirable air be prefent. In a ftrong heat it boils, and emits fumes; during which time, if expofed to the air, its calcination proceeds with confiderable rapidity. If melted lead be poured into a box previoufly rubbed with chalk to prevent its action on the wood, and be continually agitated, it will concrete into feparate grains, of confiderable ufe in various mechanical operations, particularly that of weighing. Lead is brittle at the time of congelation. In this ftate it may be broken to pieces with a hammer, and the cryftallization of its internal parts will exhibit an arrangement in parallel lines.

LEAD. Characters of lead. Granulated.

This metal, during the progrefs of heat, firft becomes converted into a dufky powder, which by a continuation of the heat becomes white, yellow, and afterwards of a bright red inclining to orange colour, called minium, or red lead. The procefs requires confiderable management with regard to the heat and

Calcination. Minium, or red lead.

LEAD.

accefs of air, in the making of red lead. Many days are required for this purpofe. If the heat be too great or rapid, the lead becomes converted into a flaky fubftance, called litharge; and a ftill greater heat converts it into a clear, tranfparent, yellow glafs, which powerfully diffolves and corrodes metallic calces or earths; and on this account it ufually finds its way through the crucibles in a fhort time. It acts more difficultly on argillaceous than on filiceous earths; whence it is found that veffels made of clay mixed with broken pottery are preferable to thofe that are compofed of clay and fand. The calx of lead is a principal ingredient in moft of the modern fine white glaffes. It is more particularly calculated to form the denfe glafs ufed to correct the aberration arifing from colour in thofe telefcopes which are known by the name of achromatic; becaufe it communicates the property of feparating the coloured rays from each other in greater angles than obtain in alkaline glaffes at equal angles of mean refraction. The imperfection which moft confiderably affects this kind of glafs is, that its denfity is feldom uniform throughout. The irregularities fhew themfelves in the form of veins, which greatly difturb the regular refraction.

Litharge and glafs of lead.

Achromatic telefcope.

Lead is not much altered by expofure to air or water: though the brightnefs of its furface, when cut or fcraped, very foon goes off. It is probable that a thin ftratum of calx is formed on the furface, which defends the reft of the metal from corrofion.

Action of air and water on lead:

Moft of the acids attack lead. The vitriolic acid does not act upon it, unlefs it be concentrated and boiling. Vitriolic acid air efcapes during its procefs,

—of vitriolic acid.

LEAD.

cefs, and the acid is decompofed. When the diftillation is carried on to drynefs, a faline white mafs remains, a fmall portion of which is foluble in water, and is the vitriol of lead: it affords cryftals. The refidue of the white mafs is a calx of lead.

Combination of nitrous acid and lead.

Nitrous acid acts ftrongly on lead, and converts it into a white calx if the acid be concentrated; but if it be more diluted, the calx is diffolved, and forms a nitre of lead which is cryftallizable, and does not afford a precipitate by cooling. It detonates on ignited coals. Lime and alkalis decompofe the nitrous folution of lead. The vitriolic acid added to this folution combines with the metallic calx, and falls down. The marine acid in the fame manner carries down the lead, and forms a combination called plumbum corneum, which is more foluble in water than the horn filver.

Plumbum corneum;

Marine acid acts directly on lead by heat, which it calcines, and diffolves part of its calx. The marine falt of lead is cryftallizable.

—marine acid;

The acetous acid diffolves lead and its calces; though probably the accefs of air may be neceffary for the folution of the metal itfelf in this acid. White lead, or cerufe, is made by rolling leaden plates fpirally up, fo as to leave the fpace of about an inch between each coil, and placing them vertically in earthen pots, at the bottom of which is fome good vinegar. The pots are to be covered, and expofed for a length of time to a gentle heat in a fand bath, or by bedding them in dung. The vapour of the vinegar, affifted by the tendency of the lead to combine with the pure part of the air which is prefent, corrodes the lead, and converts the

—acetous acid.

White lead, or cerufe.

LEAD.

external portion into a white calx, which comes off in flakes when the lead is uncoiled. The plates are thus treated repeatedly until they are corroded through. Ceruse is the only white substance used in oil paintings. It may be dissolved without difficulty in the acetous acid, and affords a crystallizable salt, called sugar of lead from its sweet taste.

Sugar of lead.

This, like all the preparations of lead, is a most deadly poison.

Action of liver of sulphur on lead:

Liver of sulphur precipitates lead from its solutions, the sulphur falling down in combination with the lead.

—of alkalis:

Pure alkaline solutions dissolve a small portion of lead, and corrode a considerable quantity: the solution is said to give a black colour to the hair.

—oils.

Oils dissolve the calces of lead, and become thick and consistent; in which state they are used as the basis of plasters, cements for water works, paint, &c.

Habitudes in the dry way.

In the dry way, lead alone is calcined and vitrefied. When fused with fixed alkaline salts, it is converted into a dark-coloured scoria, partly soluble in water. The neutral salts in general are not acted upon by lead. Nitre calcines this metal when heated with it, though scarcely any commotion or apparent flame is produced by its action. Sulphur readily dissolves it in the dry way, and produces a brittle compound, of a deep grey colour and brilliant appearance, which is much less fusible than lead itself; a property which is common to all the combinations of sulphur with the more fusible metals.

The

LEAD.

The phoſphoric acid, expoſed to heat together with charcoal and lead, becomes converted into phoſphorus, which combines with the metal. This combination does not greatly differ from ordinary lead: it is malleable, and eaſily cut with a knife; but it loſes its brilliancy more ſpeedily than pure lead; and, when fuſed upon charcoal with the blow-pipe, the phoſphorus burns, and leaves the lead behind.

Habitudes with phoſphoric acid.

Lead decompoſes ſal ammoniac by the aſſiſtance of heat: its calces unite with the marine acid of that ſalt in the cold, and diſengage its volatile alkali. When volatile alkali is obtained by diſtilling ſal ammoniac with the calces of lead, the reſidue conſiſts of plumbum corneum.

Decompoſition of ſal ammoniac:

Litharge fuſed with common ſalt decompoſes it; the lead unites with marine acid, and forms a yellow compound, at preſent uſed in this country as a pigment, for which an excluſive privilege has been granted. The alkali either floats at top, or is volatilized by the heat if ſtrongly urged. The ſame decompoſition takes place in the humid way, if common ſalt be macerated with litharge; and the ſolution will contain cauſtic alkali.

—of common ſalt.

Page 122.

Lead unites with moſt of the metals. Gold and ſilver are diſſolved by it in a ſlight red heat. Both theſe metals are ſaid to be rendered brittle by a ſmall admixture of lead, though lead itſelf is rendered more ductile by a ſmall quantity of them. Platina forms a brittle compound with lead; mercury amalgamates with it; but the lead is ſeparated from the mercury by agitation, in the form of an impalpable black powder,

Combinations of lead with metals.

LEAD.

powder, vital air being at the fame time abforbed. The prefence of vital air is indifpenfably neceffary in this procefs. Copper and lead do not unite but with a ftrong heat. If lead be heated fo as to boil and fmoke, it foon diffolves pieces of copper thrown into it; the mixture when cold is brittle. The union of thefe two metals is remarkably flight; for upon expofing the mafs to a heat no greater than that in which lead melts, the lead almoft entirely runs off by itfelf. This procefs, which is peculiar to lead with copper, is called eliquation. The coarfer forts of lead, which owe their brittlenefs and granulated texture to an admixture of copper, throw it up to the furface on being melted by a fmall heat. Iron does not unite with lead, as long as both fubftances retain their metallic form. Tin unites very eafily with this metal, and forms a compound which is much more fufible than lead by itfelf, and is for that reafon ufed as a folder for lead. Two parts of lead and one of tin form an alloy more fufible than either metal alone: this is the folder of the plumbers. Bifmuth combines readily with lead, and affords a metal of a fine clofe grain, but very brittle. A mixture of eight parts bifmuth, five lead, and three tin, will melt in a heat which is not fufficient to caufe water to boil. Regulus of antimony forms a brittle alloy with lead. Wolfram unites with it into a fpongy ductile compound, which fplits into leaves when hammered. Nickel, cobalt, manganefe, and zinc, do not unite with lead by fufion.

Combinations of lead and copper; decompofed by eliquation, or by low heat.

Plumbers folder.

Fufible mixture.

All the calces of lead are very eafily revived. Minium, when expofed to a ftrong heat, gives out part of

Revival of the calces of lead.

of the vital air it abforbed during its calcination; but, like the other calces of this metal, it requires the addition of fome combuftible fubftance for its complete revival. A familiar inftance of this revival is feen by expofing the common wafers to the flame of a candle. Thefe wafers are coloured with minium, which is revived by the heat and inflammable fubftance of the wafer, fo that it falls down in metallic globules.

Native lead and its ores.

Lead is found native, though feldom; and alfo in the form of a calx, called native cerufe, or lead ochre, or lead fpar of various colours, red, brown, yellow, green, blueifh, and black.

Analyfis of calciform ores.

Thefe ores, when freed as much as poffible from earthy matter, may be diffolved in diluted nitrous acid. Calx of iron is ufually thrown down from the folution by boiling. If the lead be then precipitated by the mild mineral alkali, and weighed, 132 grains of the dry precipitate will correfpond with 100 grains of lead in the metallic ftate. If the precipitate be fufpected to contain copper, it may be feparated by digefting in volatile alkali. If it be fuppofed to contain filver and copper, the precipitate may again be diffolved in nitrous acid, and feparated by the addition of marine acid; which combining with the metal, produces luna cornea, and plumbum corneum; the latter of which, being foluble in 30 times its weight of boiling water, may be wafhed off, while the filver remains undiffolved; or the filver, if alone in the precipitate, may be taken up by volatile alkali, which will leave the calx of lead of the fame value with regard to weight

LEAD.

Native falts of lead.

weight as the foregoing. Lead is alfo found mineralized by the vitriolic and the phofphoric acids: this laft is of a greenifh colour, arifing from a mixture of iron. The vitriol of lead is foluble in about 18 times its weight of water. One hundred and forty-three grains of the dried falt reprefent 100 grains of lead. The phofphoric lead ore may be

Humid analyfis of phofphoric lead ore.

diffolved in nitrous acid by means of heat, except a few particles of iron, which remain at the bottom. By the addition of vitriolic acid the lead is thrown down in the form of white flakes of vitriol; which, when wafhed and dried, difcover the quantity of lead they contain, by the fame allowance of 143 grains of the falt to 100 grains of metallic lead. The remaining folution, being evaporated to drynefs, affords phofphoric acid.

Sulphureous ore of lead; or galena.

Lead is abundantly found in combination with fulphur, in the form of heavy, fhining, black, or blueifh lead-coloured cubical maffes, whofe corners are ufually truncated; its texture is laminated, and its hardnefs variable. This is called galena, or potters lead ore. Moft lead ores contain more or lefs of filver. When antimony enters into its compofition, the texture is radiated or filamentous. There are alfo lead pyrites, which contain a confiderable proportion of iron and fulphur; and red lead fpar, which confifts of lead mineralized by fulphur and arfenic: this is very fcarce.

Analyfis of fulphurated lead.

If fulphurated lead be boiled in nitrous or marine acid of a moderate ftrength, the fulphur may be obtained pure, and collected on a filter. When iron or

LEAD.

or ſtony particles are contained among the undiſ-ſolved part, the ſulphur may be ſeparated by digeſtion in a ſolution of cauſtic fixed alkali, which converts it into liver of ſulphur, and leaves the other inſo-luble matters behind. If the firſt ſolution be made with nitrous acid, it may contain ſilver and lead, which, after precipitation by mild mineral alkali, may be ſeparated by the volatile alkali, as mentioned in the humid analyſis of the calciform ores: when the marine acid is uſed for the ſolution of the ore, a large quantity of plumbum corneum ſeparates, for want of a ſufficient quantity of water to diſſolve it. This requiſite quantity of water muſt be added to diſſolve the ſalt before the precipitate is made by the fixed alkali.

Revival of lead by the blow-pipe.

All the ores of lead, except the phoſphoric, are re-ducible to the metallic ſtate by diſſipating their vola-tile contents by the blow-pipe on a piece of charcoal. In the large way, they are revived by fuſion with charcoal.

Uſes of lead.

The ores of this metal are abundantly found in the mine counties of England, and in various other parts of the globe. Its uſes are numerous, and ſcarcely need be mentioned. Its calces have been already mentioned as of great uſe as a pigment, and in the manufacture of glaſs. Lead is caſt into thin ſheets for covering buildings, making water-pipes, and vari-ous other uſes; and this is rolled between two cylin-ders of iron, to give it the requiſite uniformity and thinneſs. Lead is thought, and with ſome reaſon, to be not perfectly innocent even for water-pipes, and much leſs ſo for any other kind of veſſels. The work-men

LEAD.

men in any of the preparations of lead are generally ſubject to a peculiar colic, and paralytic diſorders; which moſt probably ariſe from the internal uſe of the metal: for it is a fact that theſe workmen are not ſufficiently cautious in waſhing their hands, or removing ſuch particles of lead, or its preparations, as may caſually intermix with their food.

CHAP. VI.

CONCERNING COPPER.

COPPER. Character of copper.

COPPER is a metal of a peculiar reddiſh brown colour; hard, ſonorous, very malleable, and ductile; of conſiderable tenacity, and of a moderate ſpecific gravity. At a degree of heat far below ignition the ſurface of a piece of poliſhed copper becomes covered with various ranges of priſmatic colours, the red of each order being neareſt the end which has been moſt heated; an effect which muſt doubtleſs be attributed to calcination, the ſtratum of calx being thickeſt where the heat is greateſt, and growing gradually thinner and thinner towards the colder part. A greater degree of heat calcines it more rapidly, ſo that it contracts thin powdery ſcales on its ſurface, which may be eaſily rubbed off; the flame of the fuel becoming at the ſame time of a beautiful blueiſh green colour. In a ſtrong white heat, nearly the ſame as is neceſſary to melt gold or ſilver, it melts, and exhibits a blueiſh green flame; by a violent heat it boils, and is volatilized partly in the metallic ſtate.

See Newton's Optics.

Corroſion of copper:

Copper ruſts in the air; but the corroded part is very thin, and preſerves the metal beneath from further corroſion.

—and ſolution in vitriolic acid.

The vitriolic acid, when concentrated and boiling, diſſolves copper. A brown thick fluid, containing calx of copper, and a portion of the calx combined with

COPPER.

with vitriolic acid, is found at the bottom of the solvent. If water be added to this, it forms a blue solution of copper, which by evaporation affords blue cryſtals, that require about four times their weight of water to diſſolve them. This ſolution lets fall a calx of copper of a green colour by long expoſure to the air.

Vitriolic combinations and precipitates.

The ſolutions of copper in vitriolic acid are ſlightly cauſtic. Magneſia, lime, and the fixed alkalis, precipitate the metal from them in the form of calx. Volatile alkali precipitates all the ſolutions of copper; but rediſſolves the calx, and produces a deep blue colour. Copper is precipitable from moſt of its ſolutions in the metallic ſtate by the addition of iron: a clean plate of iron ſoon becomes covered with a coating of copper when immerſed in the ſolution: hence the volatile alkali, and the application of iron, are conſidered as the teſts of the preſence of copper. There are certain mineral waters in Hungary, Sweden, Ireland, and in various parts of England, which contain vitriol of copper, and from which it is precipitated by the addition of pieces of old iron.

Nitrous combination of copper.

Nitrous acid diſſolves copper with great rapidity, and diſengages a large quantity of nitrous gas. Part of the metal falls down in the form of a calx; and the filtrated or decanted ſolution, which is of a much deeper blue colour than the vitriolic ſolution, affords cryſtals by ſlow evaporation. This ſalt is deliqueſcent, very ſoluble in water, but moſt plentifully when the fluid is heated. Its ſolution, expoſed to the air in ſhallow veſſels, depoſits a calx of a green colour. Lime precipitates the metal of a pale blue; fixed alkalis, of a blueiſh

COPPER.

iſh white. Volatile alkali throws down blueiſh flocks, which are quickly rediſſolved, and produce a lively blue colour in the fluid.

Solution of copper in marine acid:

Marine acid does not readily diſſolve copper, unleſs it be concentrated and boiling. The ſolution is of a deep brown colour; but, on ſtanding for ſome time, it depoſits a ſediment, and becomes green. By careful evaporation it yields cryſtals; or, when inſpiſſated, it affords a greeniſh maſs, which deliqueſces in the air, is readily diſſolved in water, gives a green tincture to ardent ſpirit, melts in a gentle heat, takes fire from a candle, and burns with a blue flame. The marine acid diſſolves the calces of copper more readily than the metal itſelf; but the ſolution does not differ from the foregoing.

—in vegetable acids.

Vegetable acids diſſolve copper ſlowly; but in conſiderable quantity, if reſpirable air be preſent. In this, as in a number of other metallic ſolutions, it appears that the diſpoſition of the air to calcine the metal is greatly aſſiſted by the elective attraction of the acid for the metallic calx.

Effect of the preſence of air.

Vinegar does not diſſolve copper when boiling, becauſe the ſteam prevents the acceſs of the air; but the ſame acid ſtanding for a day in a copper veſſel, will contract a dangerous metallic impregnation. This circumſtance accounts for the unhappy conſequences in ſome inſtances attending the uſe of copper veſſels, which in other caſes have produced no noxious effects. Confectioners boil pickles, and even lemon juice, in clean copper veſſels, without obſerving any bad taſte or noxious conſequence to follow. We cannot however avoid heartily concurring in the gene-

COPPER.

ral opinion which now prevails, in the rejection of copper veſſels for culinary purpoſes.

Fabrication of verdigris.

Verdigris is a calx of copper prepared in large quantities near Montpellier in France, by ſtratifying copper plates with the huſks of grapes which remain after the juice has been preſſed out. Theſe ſoon become acid, and corrode the copper. A ſolution of this calx in diſtilled vinegar affords permanent cryſtals, improperly called diſtilled verdigris.

Solution of copper in fixed alkalis:

Fixed alkalis have ſome action on copper, with which they form a light blue ſolution. This, as well as the volatile alkaline ſolution, appears to ſucceed better in the cold than by the aſſiſtance of heat, for the ſame reaſon as the cold acetous acid acts upon copper; namely, the facility with which the metal is calcined by the acceſs of air.

—in volatile alkali.

Volatile alkali diſſolves copper with much greater rapidity than fixed alkalis, whether it be in the metallic or calciform ſtate; and forms a beautiful blue ſolution. This fluid has long attracted the notice of chemiſts, on account of its becoming colourleſs in cloſed veſſels; and recovering its colour, which gradually extends from the ſurface downwards, when the veſſel is opened. This effect is explained by the ſuppoſition, that the perfect ſolution of calx of copper in volatile alkali is colourleſs when the alkali is in exceſs; but that it is blue when it abounds with calx of copper: and accordingly it is found that the loſs of colour on keeping the veſſel cloſed for ſome time, and its reappearance on opening the veſſel, does not ſucceed with old ſolutions, which are permanently blue. The

air

air calcines more perfectly a portion of the fuspended copper, which gives a blue colour to the fluid until it has more intimately combined with the alkali. If this combination be made in the clofed veffel, the colour difappears; if it be made in the open veffel, the calcination of another portion goes on, and continues until the alkali is faturated, and can combine with no more: fo that the laft portion of perfect calx, which caufes the blue colour, does not feem to have entered into fo intimate a combination, for want of an excefs of alkali. The alkali does not take up any confiderable quantity when applied to copper filings; but it diffolves much more of the calces of copper. The folution does not very readily afford cryftals.

Habitudes of copper with volatile alkali:

Oils do not feem to act upon copper until they become rancid; in which cafe their difengaged acid corrodes the copper, and the oil affumes a blueifh green colour. Verdigris is foluble in ardent fpirit. Copper in the metallic ftate does not unite with earths or alkalis in the dry way: its calces enter into the compofition of glafs. In general, it does not act on the neutral falts by fufion. Nitre detonates with it but difficultly. Filings of copper are thrown upon red-hot nitre; and the refidue is a brownifh grey calx, mixed, and partly combined, with vegetable alkali. If this be wafhed with water, the remaining calx may be fufed, without other addition, into a deep opake brown glafs, ufed by enamellers.

—with oils, earths, alkalis, and neutral falts:

Sal ammoniac is decompofed by copper filings. The produce which comes over confifts of cauftic

—fal ammoniac.

 volatile

COPPER.

Habitudes of copper with ſal ammoniac:

volatile alkali, rendered blue by a ſmall portion of copper, together with alkaline air, inflammable air, and phlogiſticated air: the reſidue conſiſts partly of marine ſalt of copper and calx. In this experiment we find that the copper detains the acid; while the volatile alkali, being ſet at liberty, comes over into the receiver. The inflammable and phlogiſticated air cannot ſo clearly be accounted for, as they may ariſe either from part of the alkali being decompoſed into its firſt principles; or the inflammable air may be ſupplied during the ſolution of the copper; in which caſe it will proceed from the phlogiſton of that metal, according to the hypotheſis of Stahl; or from a decompoſition of part of the water of cryſtallization of the ſal ammoniac; the pure air of which will be communicated to the copper, in order to calcine and render it ſoluble in the marine acid, while its inflammable air comes over in the elaſtic ſtate.

—with alum:

A ſolution of alum boiled in a copper veſſel depoſits ſome earth; and the fluid exhibits ſigns of the preſence of copper by the teſt of volatile alkali. This does not ſeem to be a perfect decompoſition of the alum; but appears to be effected by virtue of the acid, which that ſalt contains in exceſs. The neutral ſalt or alum, ſaturated with its own baſis, falls down, becauſe leſs ſoluble; while the exceſs of acid, forming vitriol of copper, exhibits the blue tinge when volatile alkali is added.

—with ſulphur.

Copper unites very readily with ſulphur. If copper filings be mixed with flowers of ſulphur and a little water, the combination takes place; but it is much more

more readily effected in the dry way. This cannot be done by direct fusion, because the sulphur is burned at a much less heat than is required to fuse the copper. It may be prepared by mixing equal parts of sulphur and copper filings together, and exposing them to heat, gradually raised to ignition: or plates of copper may be stratified in a crucible with sulphur, and gradually heated as before. This compound is a blackish grey mass; and is used by dyers and callico-printers: it is distinguished by the name of æs veneris. Liver of sulphur dissolves copper both in the humid and dry way.

COPPER. Combination of copper with sulphur:

Phosphorus unites with the calx of copper: or if the phosphoric glass be exposed to heat in a crucible, together with its weight of copper filings, and about $\frac{1}{4}$ of its weight of charcoal, the phosphorus which is formed combines with the copper into a kind of pyrites, which changes by exposure to air. It loses its metallic state, and assumes a black colour.

—with phosphorus:

The combinations of copper with the metals before treated of have been already mentioned. It unites imperfectly with iron in the way of fusion. Tin very readily combines with copper at a temperature much lower than is necessary to fuse copper alone On this is grounded the method of tinning copper vessels. For this purpose, they are first scraped, or scoured; after which they are rubbed with sal ammoniac. They are then heated, and besprinkled with powdered resin, which defends the clean surface of the copper from acquiring the slight film of calx, which would prevent the adhesion of the tin to its surface. The melted tin is then poured in, and spread about.

—with metallic substances.

COPPER.

An extremely ſmall quantity adheres to the copper; which may with great juſtice be ſuppoſed inſufficient to prevent the noxious effects of the copper as perfectly as might be wiſhed.

Bronzes and bell-metal.

When tin is melted with copper, it compoſes the compound called bronze. In this metal the ſpecific gravity is always greater than would be deduced by computation from the quantities and ſpecific gravities of its component parts. The uſes of this hard, ſonorous, and durable compoſition, in the fabrication of cannon, bells, ſtatues, and other articles, are well known. Bronzes and bell-metals are not uſually made of copper and tin only, but have other admixtures, conſiſting of lead, zinc, or arſenic, according to the motives of profit, or other inducements of the artiſt. But the attention of the philoſopher is more particularly directed to the mixture of copper and tin, on account of its being the ſubſtance of which the ſpeculums of reflecting teleſcopes are made.

Metal for ſpeculums.

The metal required for this purpoſe ought to be capable of an exquiſite poliſh, hard enough to receive and retain a figure accurately ſuited to the regular reflection of light, and not ſubject to become tarniſhed by the action of the atmoſphere. Many excellent teleſcopes have been made with compoſitions of pure copper, alloyed with ſomewhat leſs than half its weight of tin. But it appears to be very well aſcertained, from the obſervations of the Aſtronomer Royal, that the ſpeculums of Mr. Edwards, whoſe compoſition was the reſult of numerous trials, are much ſuperior to any which have yet been made; and are even equal in light to achromatic

COPPER.

Edwards's method of making speculums.

matic telescopes of the same aperture, without altering the colours of objects. He first melts 32 parts of copper as fluid as possible, with one part of brass and one of silver, together with the black flux; at the same time that fifteen parts of tin are melted in a separate crucible by itself. These being taken from the fire, he pours the tin to the copper; immediately stirs the whole together with a wooden spatula, and pours it out hastily into a large quantity of cold water, which cools and granulates the composition. If the tin were fused together with the copper, or if they were to remain for any length of time in the extreme heat which is necessary to fuse this last metal, a part of the tin would be calcined, and the metal would abound more or less with small microscopic pores. If one of the pieces of the cold metal be broken, it will appear of a most beautiful bright colour, resembling quicksilver. Mr. Edwards affirms, that different kinds of copper require different doses of tin to produce the most perfect whiteness. If the dose of tin be too small, which is the fault most easily remedied, the composition will be yellowish; if it be too great, the composition will be of a grey blue colour, and dull appearance. He therefore finds by trial the quantity of tin necessary to be added in the second fusion to render the metal the most perfect. A much less degree of heat is then required to melt the compound. In the second melting he adds one part of arsenic, and immediately stirs the mixture; which he pours into the mould as soon as the fumes of the arsenic have ceased to rise. He casts the spe-

COPPER.

Metallic mixtures.

culum in fand, with the face downwards; takes it out while red-hot, and places it in hot wood-afhes to cool; without which precaution it would break in cooling *.

Copper unites with bifmuth, and forms a reddifh white alloy. With arfenic it forms a white brittle compound, called tombac. With zinc it forms the compound called brafs, and diftinguifhed by various other names, according to the proportions of the two ingredients. It is not eafy to unite thefe two metals in confiderable proportions by fufion, becaufe the zinc is burned or volatilized at a heat inferior to that which is required to melt copper; but they unite very well in the way of cementation. In the brafs works, copper is granulated by pouring it through a plate of iron, perforated with fmall holes and luted with clay, into a quantity of water about four feet deep, and continually renewed. To prevent the dangerous explofions of this metal, it is neceffary to pour but a fmall quantity at a time. There are various methods of combining this granulated copper, or other fmall pieces of copper, with the vapour of zinc. Calamine, which is an ore of zinc, is pounded, and

* As the conftruction of telefcopes is foreign to the immediate purpofe of this work, it has not been thought neceffary to mention the feveral precautions of Mr. Edwards in this bufinefs: but the curious operator, who may wifh to undertake the conftruction of a reflecting telefcope (the better kinds of which are not only difficult to be procured, but of confiderable price), may have recourfe to Edwards's Treatife, annexed to the Nautical Almanack for 1787; where he will find ample inftructions for that purpofe.

mixed

mixed with the divided copper, together with a portion of charcoal. These being exposed to the heat of a wind furnace, the zinc becomes revived, rises in vapour, and combines with the copper, which it converts into brass. The heat must be continued for a greater or less number of hours, according to the thickness of the pieces of copper, and other circumstances; and at the end of the process the heat, being suddenly raised, causes the brass to melt, and occupy the lower part of the crucible. The most scientific method of making brass seems to be that mentioned by Cramer *. The powdered calamine, being mixed with an equal quantity of charcoal, and a portion of clay, is to be rammed into a melting vessel; and a quantity of copper, amounting to two thirds of the weight of the calamine, must be placed on the top, and covered with charcoal. By this management the volatile zinc ascends, and converts the copper into brass, which flows upon the rammed clay: consequently, if the calamine contain lead, or any other metal, it will not enter into the brass, the zinc alone being raised by the heat.

The fabrication of brass.

A fine kind of brass, which is supposed to be made by cementation of copper plates with calamine, is hammered out into leaves in Germany; and is sold very cheap in this country under the name of Dutch gold. It is, as I find, about five times as thick as gold leaf; that is to say, it is about one sixty-thousandth of an inch thick.

Leaf brass, or Dutch gold.

* Art of Assaying Metals. London, 1764. Page 377.

If

COPPER.

Metallic mixtures.

If brafs be kept in a ftate of ignition, with contact of air, the zinc burns, and the copper remains. Whether the zinc would quit the brafs without combuftion, is not known; though there is little doubt but it might be driven off in clofe veffels.

The quantity of zinc in good brafs is about one third of its weight.

Copper unites readily with regulus of antimony; and affords a compound of a beautiful violet colour. It does not readily unite with manganefe. With wolfram it forms a dark brown fpongy alloy, which is fomewhat ductile.

Native copper, and its ores.

Copper is either found native, moftly in an impure ftate; or in the form of a calx, of a red, green, or blue colour. The native folutions of copper frequently impregnate calcareous earths, in which they depofit the metal. The turquoife ftone is the tooth of an animal penetrated with the blue calx of copper. Many ores of copper contain fulphur. Among thefe, the vitreous copper ore is of a red, brown, blue, or violet colour; fometimes cryftallized, but ufually foft enough to be cut with a knife. Some of the pyrites contain a confiderable proportion of copper, together with iron, fulphur, and clay. The grey copper ore is a fulphureous combination, containing arfenic: it is of a white, grey, or brown colour, heavy, and difficult of fufion. Blendofe copper ore is of a brown colour, hard, folid, compact, and granulated: it contains the metal, with fulphur, arfenic, zinc, and iron. Some flates, and one fpecies of coal, afford copper; and feveral waters contain

contain this metal, diſſolved in vitriolic or marine acid.

Aſſay of native copper: Native copper may be aſſayed in the humid way by ſolution in nitrous acid. If it contain gold, this metal falls untouched to the bottom, in the form of a black powder; if ſilver, it is ſoon precipitated by more copper; if iron, by boiling the ſolution for ſome time, it is gradually calcined, and falls to the bottom.

—of calciform ores: The calciform copper ores are ſoluble in acids, and may be precipitated either by iron, which affords the copper in the metallic ſtate; or by mild alkali, which throws down 194 grains of precipitate for every 100 grains of copper.

—of ſulphureous ores: Sulphureous copper ores may be powdered, and gently boiled to dryneſs in five times their weight of concentrated vitriolic acid. The whole, or moſt part, of the ſulphur flies off by this heat. The vitriolic ſalt of copper requires at leaſt four times its weight of water to diſſolve it. A ſufficient quantity being therefore added, and a poliſhed iron plate boiled in the ſolution, the copper will be precipitated. If iron be found to be mixed with the precipitate, it muſt be again diſſolved, to obtain a richer ſolution. This will depoſit pure copper, if the operation be conducted as before. If it contain other metals, they may be eaſily ſeparated by ſolution in nitrous acid.

—in the dry way. In the dry way, the ſulphureous ores of copper muſt be firſt pulverized, and ſeparated as much as poſſible from the earthy and ſtony particles; then roaſted,

COPPER.

roafted, to feparate the fulphur and arfenic; and, laftly, melted with an equal weight of M. Tillet's flux, which confifts of two parts of pounded glafs, one of calcined borax, and $\frac{1}{8}$ of charcoal. More borax may be added if the ore be poor. Alkaline fluxes are hurtful in the fufion of copper ores, becaufe the falt combines with the fulphur, and forms hepar, which diffolves part of the copper.

Treatment of copper ores in the large way.

In the large way, copper is roafted in a clofe furnace, by a flow fire, to fcorify the mixtures of iron, and other fubftances. By repeated fufions with fulphur and charcoal, the fcorified metal rifes to the top, and is fcummed off. The copper in the great Hungarian mines is faid to undergo fufion fourteen times before it is fit for fale. The roafted ore in the ifle of Anglefey is deprived of its vitriolic falt by wafhing; and the copper is precipitated by means of old iron immerfed in the water. This precipitated copper is, however, but a fmall proportion of the whole produce.

Countries where copper is found.

Copper is found in various parts of the world; in Spain, France, England, Norway, Hungary, Sweden, and elfewhere. The Japan copper is faid to be purer, and has a greater fpecific gravity, than any other copper. The wire-drawers, who require copper of extraordinary ductility, ufe the Swedifh copper. The copper mines in England are exceedingly numerous and productive. Paris mountain, on the ifle of Anglefey, contains a bed of ore forty feet in thicknefs; and is faid to produce upwards of four thoufand tons of copper annually.

The

The uſes of this metal are too numerous to be diſtinctly ſpecified. It has for ſome years paſt been applied with great ſucceſs and advantage for ſheathing the bottoms of ſhips; and ſeveral builders have lately endeavoured to introduce it as a covering for houſes. It is the lighteſt of all coverings; but whether it be more durable than ſlate, which is nearly as light, has not yet been aſcertained by experience. Copper applied to various uſes.

CHAP.

CHAP. VII.

CONCERNING IRON.

IRON.

Characters of iron.

IRON is a metal of a blueiſh white colour, of conſiderable hardneſs and elaſticity; very malleable, exceedingly tenacious and ductile, and of a moderate ſpecific gravity among metallic ſubſtances. It is much diſpoſed to ruſt by the acceſs of air, or the action of water, in the common temperature of the atmoſphere. The appearance of priſmatic colours on its poliſhed ſurface takes place long before ignition; and at ſo low a temperature, that the ſlighteſt coating of greaſe is ſufficient to prevent their appearance, by defending it from the contact of air. It may be ignited, or at leaſt rendered ſufficiently hot to ſet fire to brimſtone, by a quick ſucceſſion of blows with a hammer. When ſtruck with a flint, or other hard ſtone, it emits decrepitating ignited particles, ſuch as can be obtained from no other metal by the ſame means. Theſe particles are ſeldom larger than the two hundredth part of an inch in diameter; and, when examined by a magnifier, are found to be hollow, brittle, and of a greyiſh colour, reſembling the ſcales of burned iron. This metal is eaſily calcined by fire. A piece of iron wire, immerſed in a jar of vital air, being ignited at one end, will be entirely conſumed by the ſucceſſive combuſtion of its parts. It requires a moſt intenſe heat to fuſe it; on which account it can only be brought into the ſhape of of tools and utenfils by hammering. This high degree of infufibility would deprive it of the moft valuable property of metals, namely, the uniting of fmaller maffes into one, if it did not poffefs another fingular and advantageous property, which is found in no other metal except platina; namely, that of welding. In a white heat iron appears as if covered with a kind of varnifh; and in this ftate, if two pieces be applied together, they will adhere, and may be perfectly united by forging. Iron is thought to be the only fubftance in nature which has the property of becoming magnetical. It is highly probable, from the great abundance of this metal, that all fubftances which exhibit magnetifm do contain iron; but it muft be confeffed that there remain many experiments to be made among the earths and powders which exhibit magnetical properties, before this negative propofition, which confines magnetifm to iron, can be admitted as proved. Characters of iron.

When iron is expofed to the action of pure water, it acquires weight by gradual calcination, and inflammable air efcapes: this is a very flow operation. But if the fteam of water be made to pafs through a red-hot gun-barrel, or through an ignited copper or glafs tube containing iron wire, the iron becomes converted into a calx; while inflammable air paffes out at the other end of the barrel. This capital experiment * may be accounted for according to the ancient and modern theories. In the ancient theory, it is fuppofed that the water has combined with the iron, and difengaged its phlogifton in the form of inflammable air. Calcination of iron by water. Ancient theory.

* Of M. Lavoifier.

4 and

IRON.

Calcination of iron by water.

and confequently that, when this calx is again revived by heating a portion of it in inflammable air with a burning glafs, and water appears, at the fame time that part of the inflammable air is abforbed, the iron has imbibed phlogifton, and given out its water. Clear as this explanation appears to be, the folution afforded by the modern theory is not lefs perfpicuous. The maintainers of this theory reafon as follows: Iron has not been fhewn to be a compound fubftance; let us therefore confider it as a fimple fubftance, until we poffefs experiments which fhew the contrary. Water has been fhewn to be a compound fubftance, by the experiment of its production, by burning dephlogifticated and inflammable air together. We may fairly therefore affirm, that the inflammable air came from the water, in which we know it to exift; and that the vital air of the water, the peculiar inftrument of calcination, has combined with the iron. On the other hand, when the iron is revived in inflammable air, the water which appears is the very product of combination which was decompofed in the former inftance. For the vital air quits the iron to unite in the fluid ftate with the inflammable air; and the iron, being fet at liberty, recovers its original ftate; that is to fay, it is revived.

Modern theory

Difficulty.

That the iron, in the one inftance, attracts vital air from the water, and difengages inflammable air; and, in the other inftance, exhibits a lefs affinity with that fubftance, fo as to reftore it to its former combination; is a difficulty which, in the prefent ftate of our information, can only be accounted for by fuppofing, that the temperature in the furnace differs from that produced

duced by the burning glafs; and that thefe affinities, like moft others in chemiftry, are not the fame at all temperatures. This difficulty affects both theories alike; for it is not eafier to account for the contrary tranfitions of water and phlogifton, which mutually expel each other in the old theory, than for the tranfitions of dephlogifticated and inflammable air in the new theory.

IRON.

Calcination of iron by water.

Theory.

The philofophers who reject phlogifton infift, moreover, that the weight of the inflammable air produced, being deducted from the weight of the water made ufe of, leaves a quantity equal to the increafe the iron gains by calcination; and that by burning the whole inflammable air produced, with a quantity of vital air equal in weight to the gain of the iron, a new quantity of water is recompofed, which is equal likewife to that made ufe of. Hence they urge, that it is infinitely more probable that the inflammable air came from the water than from the iron. The latter fact, of the recompofition, is in their favour; but the former is not. For whatever the inflammable air comes from, the firft equation will be true; that is to fay, if the iron give out phlogifton, and receive water, its acceffion of weight will be equal to the difference between the water it has received, and the phlogifton it has loft; but the reproduction of the water loft will fhew that the inflammable air really correfponds with the quantity required to form* fo

* It may be urged that the two airs contain much water; and for that, as well as other reafons, their abfolute quantities cannot

IRON.

so much water, if we admit the accuracy of the experiments.

Solution of iron in the vitriolic acid.

The concentrated vitriolic acid scarcely acts on iron, unless it be boiling. When the acid is distilled to dryness from this metal, the retort is found to contain sublimed flowers of sulphur, and a white vitriolic mass, partly soluble in water: the product which comes over is volatile vitriolic acid, and vitriolic acid air. If the vitriolic acid be diluted with two or three parts of water, it dissolves iron readily, without the assistance of any other heat than is produced by the act of combination. During this solution, inflammable air escapes in large quantities. If heat be applied, the acid proceeds to dissolve more iron, and deposits a white saline mass, or pale vitriol of iron.

Martial vitriol.

The combination of vitriolic acid and iron, called martial vitriol, is much more soluble in hot than cold water; and therefore crystallizes by cooling, as well as by evaporation. The crystals are efflorescent, and

cannot be ascertained. But it is not required to ascertain their absolute quantities: for it is enough if the two airs in this recomposition be exactly in the same state as in the original experiment, by which the component parts of water were determined. If a certain portion of water be necessary to inflammable air in the elastic state, it must of course take it from the steam in the gun-barrel at the instant of its extrication, and not afterwards from the water of the receivers: this requires to be confirmed by an experiment over mercury. How far Dr. Priestley's experiments (Phil. Transf. lxxviii. and lxxix.) may effect the position, that water is a compound substance, cannot be clearly ascertained until it is shewn that the acid produced in burning the two airs does not arise from impurity in one or both of them. See page 95.

fall

IRON.

Martial vitriol.

fall into a white powder by expofure to a dry air, the iron becoming more calcined than before. A folution of martial vitriol, expofed to the air, imbibes its vital part; and a portion of the iron, becoming too much calcined to adhere to the acid, falls to the bottom in the form of ochre. The folution, as well as the cryftals it affords by evaporation, are thus rendered paler than before.

Martial vitriol is not made in the direct way, becaufe it can be obtained at lefs charge from the decompofition of martial pyrites.

Theory of the effects of vitriolic acid upon iron; according to the doctrine of phlogifton.

The different appearances which accompany the folutions of iron in the vitriolic acid, may be accounted for according to the principles either of the ancient or modern theories. In the ancient theory, iron being fuppofed to contain phlogifton, or the principle of inflammability, is calcined in both cafes; that is to fay, it gives out phlogifton *. With the concentrated acid the folution does not take place; becaufe the capacity of the mixture for heat, and confequently its abfolute quantity of heat, is too fmall to fupply what the increafed capacity of the vitriolic acid air would require, and confequently the iron is not decompofed. But when heat is applied, the phlogifton of the iron, uniting with the bafis of part of the acid, forms fulphur; which, together with another portion of the acid, rifes in the form of vitriolic acid air; at the fame time that the vital air of the decompofed acid unites with the calx of iron, which becomes foluble

* Kirwan, in Philof. Tranfact. vol. lxxii; and Effay on Phlogifton, London, 1789, page 62, or page 28 of the old edition.

IRON. Theory :

in the acid that remains: but when much water is prefent, as in the diluted acid, the heat is fupplied from the great capacity of the water; the phlogifton of the iron affumes the elaftic form; and inflammable air flies off, while the acid unites with the calx of iron, and forms vitriol. The decompofition of the acid in the former, and not in the latter cafe, is accounted for from its ftrong attraction to the water. A confiderable heat, applied with the diluted acid, calcines the iron more perfectly; which then either enters into the compofition of pale vitriol, containing a larger proportion of acid, or falls down in the form of calx. The accefs of air does the fame thing more gradually.

—according to the antiphlogiftic doctrine.

In the antiphlogiftic theory, iron is affumed to be a fimple fubftance; vitriolic acid is faid to be compofed of vital air and fulphur; and water is admitted to be decompofable. When iron therefore is applied to concentrated vitriolic acid, the principles retain their order of combination at a common temperature; but as foon as the temperature is raifed, the iron becomes calcined, by attracting vital air from part of the acid, whofe fulphur is therefore fet at liberty, and flies off with another portion of the acid, in the form of vitriolic air; while the remaining acid combines with part of the calx. But when the acid is more diluted, the water itfelf is decompofed; its inflammable air is difengaged; its vital air unites with and calcines the iron; and the vitriolic acid diffolves the calx.

The neceffity of heat being applied to the concentrated folution in the one cafe rather than the other, may be referred to the capacities of the bodies, before and

and after the change, in either theory. But it muſt be confeſſed that the cauſe of the diſengagement of vitriolic air in the one caſe, and inflammable in the other, is not ſo well ſolved. It has not been explained, upon the old theory, why the phlogiſton in one caſe unites with the acid, and forms ſulphur, and in the other flies off alone; neither has it been ſhewn, in the new theory, why the water ſhould not be decompoſed in the former inſtance, as well as the latter.

Theory of the action of vitriolic acid on iron.

The further calcination of the iron by heat, or by expoſure of the ſolution to the air, is accounted for, in the new theory, from the abſorption of more vital air. The general fact, that a definite degree of calcination is neceſſary for the moſt perfect ſolution of metals in acids, depends on attractions which have not been experimentally reſolved; but which, in the way of conjecture, may be as eaſily accounted for by one theory as by the other.

Precipitates of iron.

Vitriol of iron is decompoſed by alkalis and by lime. Cauſtic fixed alkali precipitates the iron in deep green flocks, which are diſſolved by the addition of more alkali, and form a red tincture. The mild alkali does not rediſſolve the precipitate it throws down, which is of a greeniſh white colour. Diſtillation ſeparates the acid from martial vitriol, and leaves the brown calx of iron, called colcothar.

Colcothar.

Black fecula, precipitated by aſtringents.

Vegetable aſtringent matters, ſuch as nut-galls, the huſks of nuts, logwood, tea, &c. which contain the acid of galls hereafter to be deſcribed, precipitate a fine black fecula from martial vitriol, which remains ſuſpended for a conſiderable time in the fluid, by the addition of gum arabic. This fluid is well known by

IRON.

Ink; its nature doubtful.

the name of ink. It appears to confift of the acid of galls, united to the calx of iron: but its nature has not been well determined; more efpecially by an examination of the contents of the fluid which remains after the precipitate has been completely depofited. The black fecula is not magnetical; but it is converted into a brown magnetic calx by heat. An excefs of either of the three ancient mineral acids renders ink colourlefs; but the acetous acid, or vinegar, does not. Ink becomes blacker by expofure to the air, which acidifies more completely the principle combined with the iron; but ancient writings become more and more yellow, in confequence of the efcape of the acid *. Their legibility may be reftored by the addition of infufion of galls, or gallic acid The beft method of reftoring

* Inks feem to fail chiefly on account of the fmall proportion and deftructibility of the aftringent principle, which Berthollet diftinguifhes from the gallic acid Dr. Lewis recommends the following receipt for writing-ink (Commerce of Arts, page 391): One part martial vitriol, one part powdered logwood, and three parts powdered galls, are to be infufed in one quart of vinegar, or white wine, or water, for each ounce of the vitriol, together with one ounce of gum arabic for each quart of the liquor; and fhaken for four or five times a day, during ten or twelve days; after which it may be decanted for ufe.

On the above I muft remark, that though vinegar affords a good black ink, yet Dr. Lewis has overlooked a great inconvenience attending its ufe. It acts fo ftrongly upon the quills, that the fharpnefs of the extremity of a pen ufed with this ink foon goes off, and continually wants mending. A perfect theory of ink would probably lead to great improvements in this moft ufeful fluid.

Ribaucourt, Annales de Chimie, does not approve the redundancy of aftringent matter recommended by Lewis. An abftract of his experiments may be feen, under art. INK of the Chemical Dictionary.

the

the legibility of ancient writings * confifts in fpreading a folution of the Pruffian alkali thinly with a feather over the traces of the letters; and then to touch it gently, and as nearly upon or over the letters as can be done, with a diluted acid, by means of a pointed ftick.

Manufacture of Pruffian blue.

The beautiful pigment, well known in the arts by the name of Pruffian blue, is likewife a precipitate afforded by martial vitriol. It has been made for confiderably more than half a century; but its compofition is not yet clearly afcertained. The procefs for making it is as follows: Calcine a mixture of equal parts of vegetable alkali and dried bullocks blood, until it ceafes to emit either flame or fmoke; then raife the fire, to give the mafs a low red heat. Throw the matter while red-hot into as many quarts of water as there were pounds of the original mixture, and boil it for half an hour. Decant the liquid, and wafh the coaly refidue with more water, till it comes off almoft infipid. Add this water to the former, and evaporate the whole by boiling, until it be reduced again to the former number of quarts. This is the lixivium fanguinis, or Pruffian alkali; which, if added in a proper quantity to a folution of iron, precipitates it partly in the form of calx, and partly in the form of Pruffian blue. If the marine acid be added to the precipitate, it diffolves the calciform part, and leaves the Pruffian blue much purer. Hence it appears that the whole of the alkali, in the ufual method of calcination with bullocks blood, or other animal fubftances, is not faturated with the

Pruffian alkali.

* Blagden, in Philof. Tranf. vol. lxxv. page 455.

IRON.

colouring matter, but that the unsaturated part of the alkali precipitates part of the iron in the calciform state; while the other part, combining with the colouring matter, falls down in the form of Prussian blue.

Prussian alkali made for chemical purposes.

For chemical purposes, the Prussian ley is produced, by boiling the alkali upon Prussian blue ready formed. The calx of iron is thus deprived of the colouring matter by the alkali, to which it has a greater affinity, and which it only quits when there is another acid present to unite with the alkali; as in the just-mentioned instance of the solution of iron, where a double affinity takes place. The Prussian alkali, prepared in either way, contains some iron. It can be had pure in no other way than by directly combining the pure colouring matter with a pure alkali.

Acid of Prussian blue.

The habitudes of this colouring matter denote it to be an acid. If the Prussian alkali be boiled in a retort with weak vitriolic acid, the colouring matter comes over in the form of an inflammable air, which will be absorbed by water placed in the receiver. As a portion of vitriolic acid likewise comes over, a second distillation is necessary to be made, with the addition of chalk. The vitriolic acid, by this means forming selenite, is detained; while the Prussian acid passes over totally before one-fourth of the water is distilled off.

Combinations of Prussian acid.

The colouring matter of Prussian blue is not only seized by the fixed alkalis, but likewise by the volatile alkali, by lime, by magnesia, and by ponderous earth; with which it forms peculiar compounds, capable of precipitating Prussian blue, by double affinity, from the solutions of iron in acids. Various metals likewise com-

combine with it. Alkalis, or lime, combined with the Pruffian acid, are ufed as tefts to afcertain the prefence and quantity of iron in folution. But all the alkaline or earthy combinations, produced by applying thofe fubftances to Pruffian blue, contain iron, which falls down in the form of the blue precipitate when an acid is added. For this reafon they cannot be ufed in accurate experiments, unlefs a previous trial has been made of the quantity a known proportion of the proof liquor is capable of precipitating.

IRON.

Caution in ufing proof liquors.

If the dephlogifticated or aërated marine acid be mixed with the Pruffian acid, the former refumes the ftate of common marine acid; while the latter acquires a much ftronger fmell, and appears to be more volatile. In this fituation it does not form Pruffian blue with the folutions of iron; but affords a green precipitate, which becomes blue by expofure to the light, or by the addition of volatile vitriolic acid.

Experiments on Pruffian acid.

If martial vitriol be added to the dephlogifticated or aërated marine acid, and a folution of Pruffian alkali be poured in, the green precipitate which is formed is again diffolved; but it may be precipitated of a blue colour by the addition of volatile vitriolic acid, or martial vitriol, or iron alone.

In the inftances laft mentioned we may perceive that the effects depend on the dephlogiftication or addition of vital air to the Pruffian acid, accordingly as we adopt the ancient or the modern theory. The green precipitate, which may be confidered either as dephlogifticated Pruffian blue, or as Pruffian blue combined with vital air, becomes common Pruffian blue

Theory.

IRON.

blue by the action of light; which, as we have frequently had occasion to remark, operates in many instances in a manner contrary to that of combustion; that is to say, it either adds phlogiston, or expels vital air, or does both. By this action therefore the Prussian blue returns to its original state. The addition of volatile vitriolic acid must produce a like effect; for this acid is phlogisticated according to the old theory, or is deficient in vital air according to the new: it is therefore disposed either to phlogisticate the green precipitate, or to attract vital air from it; which is all that it requires to convert it into common Prussian blue. The same theories manifestly apply to the green precipitate, which is redissolved; for in whatever state of combination it may be supposed to remain, as to the order or arrangement of the principles which are united in the fluid, the addition of volatile vitriolic acid, or common vitriol, or iron in the metallic state, will impart phlogiston, or attract vital air; the absence of the one, or redundance of the other of which, is supposed, according to the respective theories, to cause the difference between it and Prussian blue.

Theory of the effects of aerated marine acid on Prussian acid.

Experiment.

If the Prussian acid be impregnated more strongly with the dephlogisticated or aërated marine acid, and then exposed to the action of light, it assumes new properties. It no longer combines with iron precipitated from its solutions; its smell is entirely different from that which it before possessed; and now resembles an aromatic oil, the greatest part of it separating from the water, at the bottom of which it flows in the form of an oil. This fluid however is not inflam-

mable.

mable. By a gentle heat it riſes in the form of a vapour, not ſoluble in water: and in time it aſſumes the form of ſmall cryſtals. Pruſſian acid cannot be reſtored after it has undergone theſe changes. Their theory is not known.

Diſcovery of the component parts of Pruſſian acid.

Various experiments have been made to diſcover the component parts of the Pruſſian acid. If equal parts of pulveriſed charcoal and vegetable alkali be made red-hot for a quarter of an hour in a crucible, and ſome ſal ammoniac in ſmall pieces be then briſkly ſtirred down into the maſs, the ammoniacal vapours will ſoon ceaſe. The ignited matter being then thrown into water, affords a lixivium equal to the beſt which is made with blood. From theſe, and other experiments, it was concluded that its component parts are fixed air, volatile alkali, and the principle of inflammability, or phlogiſton. Later experiments appear to have decided the queſtion ſomewhat more accurately. When the acid has been converted, by means of the dephlogiſticated or aërated marine acid, into that ſtate which affords a green precipitate with iron, it emits alkaline air upon the addition of lime, or a pure alkali. If the lime, or alkali, be afterwards ſaturated by the addition of ſome other acid, the Pruſſian acid is not diſengaged, or reſtored, but is no where found; hence it follows, that the alkaline air was one of the principles of the Pruſſian acid, which is deſtroyed: and as the lime or alkali uſed in this decompoſition is found to be in a mild ſtate, that is to ſay, combined with fixed air, though it did not contain that ſubſtance before; it is clear that the other principle of the Pruſſian acid is fixed air.

The

IRON.

Component parts of Pruſſian acid.

The common Pruſſian acid conſiſts therefore of volatile alkali, united with the baſe of fixed air, or that ſubſtance which, in combination with vital air, forms the acid called fixed air. When the Pruſſian acid receives vital air, and is converted into the ſtate proper to afford the green precipitate, it then appears to conſiſt of the ſame principles as the mild or concrete volatile alkali, though probably in a different order of combination; and this order ſeems to be deranged by the addition of the lime, or the fixed alkali, which attracts thoſe principles that form fixed air, at the ſame time that the principles which form volatile alkali fly off in the elaſtic ſtate.

The component parts of Pruſſian acid will conſequently be phlogiſticated air, inflammable air, and fixed air, or its baſe; all which are afforded by animal ſubſtances; but they do not form this peculiar combination in any caſe yet known, excepting that in which an alkali is preſent when thoſe ſubſtances are decompoſed by fire *.

Action of nitrous acid on iron.

Concentrated nitrous acid acts very ſtrongly upon iron filings, much nitrous air being diſengaged at the ſame time. The ſolution is of a reddiſh brown, and depoſits the calx of iron after a certain time; more eſpecially if the veſſel be left expoſed to the air. A diluted nitrous acid affords a more permanent ſolution

* For a fuller account of this ſubject conſult Scheele's Eſſays; the Opuſcula, or Chemical Eſſays, of Bergman; and the Annales de Chimie, vol. i.; the latter of which contains an abſtract of a valuable memoir of Berthollet, read before the Royal Academy of Sciences at Paris in the year 1787.

of

of iron, of a greenifh colour, or fometimes of a yellow colour: neither of the folutions affords cryftals; but they depofit the calx of iron by boiling, at the fame time that the fluid affumes a gelatinous appearance. This magma, by diftillation, affords fuming nitrous acid, much nitrous air, and fome phlogifticated air; a red calx being left behind, which, in all probability, retains moft of the vital air of the acid.

Precipitates of iron from nitrous acid.

If vegetable alkali be added to the nitrous folution of iron, a brown precipitate falls down; of which a fmall quantity is rediffolved by the alkali. Mild vegetable alkali feparates a yellowifh calx, which foon becomes of a beautiful orange red colour. If the mixture be agitated during the effervefcence, the precipitate is rediffolved in much greater quantity than by the pure vegetable alkali; doubtlefs by the medium of the fixed air. This folution is known by the name of Stahl's martial alkaline tincture, and is of a fine red colour, which however is impaired by time. Pure volatile alkali feparates a deep green and almoft black precipitate from the nitrous folution of iron. The mild volatile alkali rediffolves the iron, which it feparates from the acid; and forms an alkaline tincture of a more lively colour than that of Stahl.

Martial alkaline tincture.

Action of marine acid on iron.

Diluted marine acid rapidly diffolves iron, at the fame time that a large quantity of inflammable air is difengaged, and the mixture becomes hot. In this, as well as in the vitriolic folution of iron, the fame quantity of alkali is faid to be required to faturate the acid as before the folution; whence it is inferred that the acid is not decompofed, but that the calcination

tion

IRON.

tion is effected by the vital air of the water: whence also it appears to follow, that the inflammable air muft be afforded from the decompofed water, and not from the metal. It muft however be remarked, that this fact, as well as moft of thofe upon which the rejection of phlogifton, or the inflammable principle, is grounded, are controverted by the philofophers who maintain the exiftence of that principle.

Marine folution of iron.

The marine folution of iron is of a yellowifh green colour, and is much more permanent than the folutions of that metal in the vitriolic or nitrous acids; though, like all the other folutions of iron, it depofits its metal by expofure to the air. By evaporation it affumes the confiftence of fyrup, in which needle-formed and deliquefcent cryftals appear. Some chemifts affirm, that the acid quits the iron by diftillation, though much more difficultly than either the nitrous or vitriolic acid; but this interefting experiment has not been made fince the improvements of chemiftry have led philofophers to attend to fuch products as appear in the permanently elaftic ftate.

Precipitates.

The marine folution of iron is decompofed by lime and by alkalis; but the precipitates are more eafily reduced to the metallic ftate than thofe afforded by other acids. Liver of fulphur, hepatic air, and aftringents, decompofe this, as well as the other folutions of iron; and the pure Pruffian alkali throws down a very fine blue precipitate.

Action of fixed air on iron:

Fixed air, diffolved in water, combines with a confiderable quantity of iron, in proportion to its mafs.

—and vinegar.

Vinegar fcarcely diffolves it, unlefs by the affiftance of the air.

IRON.

Action of earths, &c. on iron.

In the dry way, this metal does not combine with earths, unless it be previously calcined; in which case it assists their fusion, and imparts a green colour to the glass. It appears to combine with alkalis by fusion. Nitre detonates strongly with it, and becomes alkalized. Sal ammoniac is decomposed by it. Two parts of iron filings, triturated with one part of sal ammoniac, and exposed to distillation, afford about one part of liquid volatile alkali, contaminated by a small portion of iron. Some inflammable air comes over in this distillation, either from the iron, or from the water contained in the sal ammoniac: the residue consists of iron united to marine acid. A medical preparation is made by subliming sal ammoniac from a small portion of iron filings; which gives part of the salt a yellow colour. The calx of iron decomposes sal ammoniac by seizing its acid, even in the cold.

Combination of iron with sulphur in the humid way.

Sulphur combines very readily with iron, in the dry, and even in the humid way, though neither of these substances is scarcely at all soluble in water. A mixture of iron filings and flowers of sulphur being moistened, or made into a paste, with water, becomes hot, swells, adheres together, breaks, and emits watery vapours of an hepatic smell. If the mixture be considerable in quantity, as for example, one hundred pounds, it takes fire in twenty or thirty hours, as soon as the aqueous vapours cease. This effect may be explained without difficulty in a general way, though the circumstances require to be more minutely examined:—Iron, sulphur, and water, are placed in contact. The iron is very sparingly soluble in water*;

Spontaneous inflammation.

* Annales de Chimie, vol. i. 220.

and

IRON.

Theory of the inflammation of iron and sulphur:

and the sulphur is probably soluble in a small degree, as may be judged by its becoming soft in that fluid. In the ancient theory, it may be said that the sulphur combines with the calx of the iron, and expels its inflammable air or phlogiston. The heat must be deduced, in any theory, from the change of capacity, or rapid commotion, produced in the act of union. This heat volatilizes part of the sulphur, together with the inflammable air; and if the temperature be sufficiently elevated, these substances will take fire, at the moment of their extrication, by the assistance of the air of the atmosphere. In the new theory, the explanation will be nearly the same. The iron and the sulphur, being considered as simple substances, tend to combine with each other, through the medium of vital air, which calcines the iron, and is supposed to be afforded by decomposition of the water. The same decomposition extricates inflammable air from the water. This, together with the sulphur, forms hepatic air; which, flying off at the temperature of ignition, takes fire by combination with the air of the atmosphere. In this theory it may further be added, that, as sulphur and water, in contact, at an elevated temperature, afford inflammable air, which is explained by the supposition of vital air combining with the sulphur, there would be an increase of inflammation from this cause. Some doubt however may be entertained, whether sulphur be more combustible than inflammable air at any temperature, since hepatic air deposits sulphur when detonated with vital air; which must, in all probability, depend on the latter being less combustible at the temperature of inflammation. On the whole

—by the antiphlogistic hypothesis.

whole it appears, that facts and obfervations are wanting, rather than probable theories; and that it is fcarcely neceffary to purfue this inquiry more minutely in the way of argumentative difquifition. The fpontaneous combuftion of iron and fulphur with water, is evidently an effect of the fame kind as the decompofition of pyrites.

Page 144.

Union of fulphur with iron in the dry way.

Sulphur combines very readily with iron by fufion; and produces a compound of the fame nature as the pyrites, and exhibiting the fame radiated ftructure when broken. If a bar of iron be heated to whitenefs, and then touched with a roll of fulphur, the two fubftances combine, and drop down together in the fluid ftate. It is neceffary that this experiment fhould be made in a place where there is a current of air to carry off the fumes; and the melted matter, which may be received in a veffel of water, is of the fame nature as that produced by fufion in the common way, excepting that a greater quantity of fulphur is fufed by the contact of the bar of iron. The experiment of combining iron and fulphur together by fufion, has not been made with an attention to the volatile products, if any be extricated. As neither of thefe fubftances contains water, and both are fuppofed, in the new theory, to be fimple bodies, the experiment might, perhaps, afford an interefting refult.

Phofphorus and iron.

If equal parts of phofphoric glafs, and iron clippings, together with one-fixteenth of a part of pulverized charcoal, be fufed together, the mixture is very brittle, white in its fracture, and of a ftriated and granulated texture. This combination of iron with phof-

IRON.

Cold ſhort iron.

Siderite.

phoſphoric acid is found in the iron produced from bog ores, which abound in the remains of decayed vegetables. It is the cauſe of brittleneſs in the iron when cold; which occaſions that kind of iron to be called cold ſhort iron by the workmen. Phoſphorated iron was at firſt taken to be a peculiar metal; and was called ſiderite by Bergman.

Metallic combinations.

Iron unites with gold, ſilver, and platina. When heated to a white heat, and plunged in mercury, it becomes covered with a coating of that metal. Long trituration of mercurial amalgams likewiſe cauſes a coating to adhere to the ends of iron peſtles; ſmall ſteel ſprings, kept plunged beneath the ſurface of mercury in certain barometers, become brittle in proceſs of time: and the direct combination of* iron and mercury in the form of an amalgam may be obtained by triturating the filings with twice their weight of alum; then adding an equal weight or more of mercury, and continuing the friction with a very ſmall quantity of water till the union is completed. Iron and tin very readily unite together; as is ſeen in the art of tinning iron veſſels, and in the fabrication of thoſe uſeful plates of iron, coated with tin, which are generally diſtinguiſhed by the ſimple name of tin alone. The chief art of applying theſe coatings of tin conſiſts in defending the metals from calcination by the acceſs of air. After the iron plates are ſcraped, or rendered very clean by ſcouring with an acid, they are wetted with a ſolution of ſal ammoniac, and plunged into a veſſel containing melted tin; the ſurface of which is covered with pitch or

Tinning of iron plates.

* Vogel, in Crell's Annals, ii. 103. Eng. tranſ.

tallow,

tallow, to preferve it from calcination. The tin adheres to and intimately combines with the iron to a certain depth, which renders the tinned plates lefs difpofed to harden by hammering, than before, as well as much lefs difpofed to alter, by the united action of air and moifture. The procefs for tinning of iron veffels does not effentially differ from that which has already been defcribed of copper veffels. Iron does not unite with bifmuth, at leaft in the direct way. As nickel cannot be purified from iron without the greateft difficulty, it may be prefumed that thefe fubftances would readily unite, if the extreme infufibility of both did not prefent an obftacle to the chemical operator. Arfenic forms a brittle fubftance in its combination with iron. This femi-metal, which is fo abundant in the mineral kingdom, is faid to be the caufe of the brittlenefs which fome fpecimens of iron poffefs when hot, though malleable when cold. Iron, thus contaminated, is diftinguifhed by workmen by the name of red fhort iron. Cobalt forms a hard mixture with iron, which is not eafily broken. The inflammability and volatility of zinc prefent an obftacle to its combination with iron. It is not improbable, however, but that clean iron filings would unite with zinc, if that metal were kept in contact with them for a certain time, in a heat not fufficient to caufe it to rife; for it has been found that zinc may be ufed in the operation of coating iron in the fame manner as tin. Antimony unites with iron, and forms a hard brittle combination, which yields, in a flight degree, to the hammer. The combination of fulphur, and the regulus of antimony, which is commonly known by the name of antimony, is decompofed by

Combinations of iron with metallic fubftances.

IRON.

Combinations of iron with metallic substances.

by virtue of the greater affinity of the iron to the sulphur. For this purpose, five ounces of the points of nails from the farriers may be made red-hot in a crucible; one pound of pulverized ore of antimony must then be thrown into the crucible, and the heat quickly raised to fuse the whole. When the fusion is perfect, an ounce of nitre in powder may be thrown in to facilitate the separation of the scoriæ. After the mass is cooled, the antimony is found separate at the bottom of the crucible, while the iron remains in combination with the sulphur and alkali. If the proportion of the iron be considerably greater than five ounces to the pound of antimonial mineral, the regulus will be alloyed with iron. Manganese is almost always united with iron in the native state. Wolfram forms a brittle whitish-brown hard alloy, of a compact texture, when fused with white crude iron.

The habitudes of iron with the regulus of molybdena are not known.

Native iron, and its ores.

Iron is the most diffused, and most abundant, of metallic substances. Few mineral bodies, or stones, are without an admixture of this metal. Sands, clays, and the waters of rivers, springs, rain, or snow, are scarcely ever perfectly free from it. The parts of animal and vegetable substances likewise afford iron in the residues they leave after incineration. It has been found native, in large masses, in Siberia*, and in the internal parts of South America. This metal however in its native state is scarce: most iron is found

* See Bergman's Essays; Magellan's improved edition of Cronstedt's Mineralogy; and the Philos. Trans. lxxviii. 37.

in

IRON.

Ores of iron.

in the calciform ſtate, in ochres, bog ores, and other friable earthy ſubſtances, of a red, brown, yellow, or black colour. The hæmatites, or blood ſtones, are likewiſe calciform ores of iron: theſe are either of a red colour, or blue, yellow, or brown. This uſeful metal is ſo abundant, that whole mountains are compoſed of iron ſtone; whereas other metals uſually run in ſmall veins. Beſides the calciform ores of iron, which are either nearly pure, or elſe mixed with earths, as in ſpars, jaſper, boles, baſaltes, &c. iron is mineralized with ſulphur, as in the pyrites; with arſenic, in the white pyrites; or with both. An iron ore is likewiſe found, of a blue colour, and powdery appearance, which is thought to be of the ſame nature as Pruſſian blue. The coaly iron ores contain bitumen. The magnet, or loadſtone, is an iron ore, whoſe conſtitution has not yet been accurately examined. Iron is alſo found in combination with the vitriolic acid, either diſſolved in water, or in the form of vitriol.

Humid analyſis of iron ores.

To analyſe the ores of iron in the humid way, they muſt be reduced to a very ſubtle powder, and repeatedly boiled in marine acid. If the ſulphureous ores ſhould prove ſlow of ſolution, a ſmall quantity of nitrous acid muſt be added to accelerate the operation. The iron being thus extracted, the inſoluble part of the matrix only will remain. Pruſſian alkali, being added to the decanted ſolution, will precipitate the iron in the form of Pruſſian blue. This precipitate, when waſhed and dried, will be equal in weight to ſix times the quantity of metallic iron it contains; and from this iron four parts in the hundred muſt be deducted, to allow for the iron which is contained in the

Ores of iron.

Pruſſian alkali itſelf. But as this alkali, and every other preparation containing the Pruſſian acid, does not conſtantly afford the ſame quantity of iron, the moſt exact way, in the uſe of ſuch preparations, conſiſts in previouſly diſſolving a known quantity of iron in vitriolic acid; and precipitating the whole by the addition of the Pruſſian alkali. This reſult will afford a rule for the uſe of the ſame alkali in other ſolutions. For as the weight of the precipitate obtained in the trial experiment, is to the quantity of iron which was diſſolved and precipitated; ſo is the weight of the precipitate obtained from any other ſolution, to the quantity of iron ſought.

If the iron be united to any conſiderable proportion of zinc or manganeſe, the Pruſſian blue muſt be calcined to redneſs, and treated with pale nitrous acid, which will take up the calx of zinc. The manganeſe may then be diſſolved by nitrous acid, with the addition of ſugar; and the remaining iron, being diſſolved by marine acid, and precipitated by mild mineral alkali, will afford 225 grains of precipitate for every 100 grains of metallic iron.

Analyſis in the dry way.

To examine the ores of iron in the dry way, the only requiſite is fuſion, in contact with charcoal.— For this purpoſe, eight parts of pulverized glaſs, one of calcined borax, and half a part of charcoal, are to be well mixed together. Two or three parts of this flux, being mixed with one of the pounded ore, and placed in a crucible, lined with a mixture of a little clay and pounded charcoal, with a cover luted on, is to be urged with the ſtrong heat of a ſmith's forge for half an hour. The weight of the ore, in this experiment,

ment, ſhould not exceed 60 grains. Other proceſſes for determining the contents, or metallic product, of iron ores, are inſtituted by performing the ſame operations in the ſmall, as are intended to be uſed in the large way.

In the large iron works, it is uſual to roaſt or calcine the ores of iron previous to their fuſion; as well for the purpoſe of expelling ſulphureous or arſenical parts, as to render them more eaſily broken into fragments of a convenient ſize for melting. The mineral is melted, or run down, in large furnaces from 16 to 30 feet high; and variouſly ſhaped, either conical or elliptical, according to the opinion of the iron-maſter. Near the bottom of the furnace is an aperture for the inſertion of the pipe of large bellows, worked by water or ſteam, or of other machines for producing a current of air; and there are alſo holes at proper parts of the edifice, to be occaſionally opened, to permit the ſcoriæ and the metal to flow out, as the proceſs may require. Charcoal, or coke, with lighted bruſhwood, is firſt thrown in; and when the whole inſide of the furnace has acquired a ſtrong ignition, the ore is thrown in by ſmall quantities at a time, with more of the fuel, and commonly a portion of limeſtone, as a flux: the ore gradually ſubſides into the hotteſt part of the furnace, where it becomes fuſed; the earthy part being converted into a kind of glaſs; while the metallic part is reduced by the coal, and falls through the vitreous matter to the loweſt place. The quantity of fuel, the additions, and the heat, muſt be regulated, in order to obtain iron of any deſired quality; and this quality muſt likewiſe, in the firſt

Smelting of iron in the large way.

Y 4 product,

IRON.

product, be neceſſarily different, according to the nature of the parts which compoſe the ore.

States of iron.

The iron which is obtained from the ſmelting furnaces is not pure; and may be diſtinguiſhed into three ſtates:—white crude iron, which is brilliant in its fracture, and exhibits a cryſtallized texture, more brittle than the other kinds, not at all malleable, and ſo hard as perfectly to withſtand the file: grey crude iron, which exhibits a granulated and dull texture when broken; this ſubſtance is not ſo hard and brittle as the former, and is uſed in the fabrication of artillery, and other articles which require to be bored, turned, or repaired: and black caſt iron, which is ſtill rougher in its fracture; its parts adhere together leſs perfectly than thoſe of the grey crude iron: this is uſually fuſed again with the white crude iron.

The three kinds of crude iron.

Refining of iron.

Whenever crude iron, eſpecially the grey ſort, is fuſed again with contact of air, it emits ſparkles, loſes weight, and becomes leſs brittle. In order to convert it into malleable iron, it is placed on a hearth, in the midſt of charcoal, urged by the wind of two pair of bellows. As ſoon as it becomes fuſed, a workman continually ſtirs it with a long iron inſtrument. During the courſe of ſeveral hours it becomes gradually leſs fuſible, and aſſumes the conſiſtence of paſte. In this ſtate it is carried to a large hammer, the repeated blows of which drive out all the parts that ſtill partake of the nature of crude iron ſo much as to retain the fluid ſtate. By repeated heating and hammering more of the fuſible iron is forced out; and the remainder, being malleable, is formed into a bar, or other form, for ſale.

Crude

Cr[illegible] upwards of one-fourth of its weight in [illegible] procefs of refining.

Bar iron.

Purified, or bar iron, is foft, ductile, flexible, malleable, and poffeffes all the qualities which have been enumerated in this chapter, as belonging exclufively to iron. When a bar of iron is broken, its texture appears fibrous; a property which depends upon the mechanical action of the hammer, while the metal is cold. Ignition deftroys this fibrous texture, and renders the iron more uniform throughout; but hammering reftores it.

Iron converted into fteel by cementation.

If the pureft malleable iron be bedded in pounded charcoal, in a covered crucible, and kept for a certain number of hours in a ftrong red heat (which time muft be longer or fhorter, according to the greater or lefs thicknefs of the bars of iron), it is found that by this operation, which is called cementation, the iron has gained a fmall addition of weight, amounting to about the hundred and fiftieth, or the two hundredth part; and is remarkably changed in its properties. It is much more brittle and fufible than before. Its furface is commonly bliftered when it comes out of the crucible; and it requires to be forged, to bring its parts together into a firm and continuous ftate. This cemented iron is called fteel. It may be welded like bar iron; but its moft ufeful and advantageous property is that of becoming extremely hard when ignited, and plunged in cold water. The hardnefs produced is greater in proportion as the fteel is hotter, and the water colder. The colours which appear on the furface of fteel flowly heated, are yellowifh white, yellow, gold colour, purple, violet, deep blue, yellowifh

IRON.

Tempering.

yellowifh white; after which the ignition takes place. Thefe figns direct the artift in tempering or reducing the hardnefs of fteel to any determinate ftandard. If fteel be too hard, it will not be proper for tools which are intended to have a fine edge, becaufe it will be fo brittle that the edge will foon become notched; it may even be rendered friable by too much heat; on the contrary, if it be too foft, it is evident that the edge will bend or turn. Some artifts ignite their tools, and plunge them in cold water; after which they brighten the furface of the fteel upon a ftone: the tool being then laid upon charcoal, or upon the furface of melted lead, or placed in the flame of a candle, gradually acquires the defired colour; at which inftant they plunge it into water. If a hard temper be defired, the piece is dipped again, and ftirred about in the cold water as foon as the yellow tinge appears. If the purple appear before the dipping, the temper will be fit for gravers, and tools ufed in working upon metals; if dipped while blue, it will be proper for fprings, and for inftruments ufed in the cutting of foft fubftances, fuch as cork, leather, and the like; but if the laft pale colour be waited for, the hardnefs of the fteel will fcarcely exceed that of iron. When foft fteel is heated to any one of thefe colours and then plunged in water, it does not acquire nearly fo great a degree of hardnefs as if previoufly made quite hard and then reduced by tempering. The degree of ignition required to harden fteel, is different in the different kinds. The beft kinds require only a low red heat. The harder the fteel, the more coarfe and granulated its fracture will be; and as this is not completely remedied by the fubfequent

The proceffes for hardening and tempering of fteel.

fequent tempering, it is advifable to employ the leaft heat capable of affording the requifite hardnefs.

It is a circumftance worthy of remark, that fteel has a lefs fpecific gravity when hardened than when foft; but there are no circumftances, upon which a probable connection between thefe two properties, namely the increafed hardnefs, and the diminifhed fpecific gravity, can be made out.

The ufual time required for the cementation of a fmall bar of fteel is from fix to ten hours; but in the large way they employ four or five days. If the cementation be continued too long, the fteel becomes porous, brittle, of a darker fracture, more fufible, and incapable of being forged or welded. On the contrary, fteel cemented with earthy infufible powders, is gradually reduced to the ftate of forged iron again. Simple ignition produces the fame effect; but is attended with calcination of the furface. The texture of fteel is rendered more uniform by fufing it before it is made into bars: this is called caft fteel; and is rather more difficultly wrought than common fteel, becaufe it is more fufible, and is difperfed under the hammer if heated to a white heat.

Caft fteel.

It is often found of advantage in the arts to convert the outfide of any tool or implement into fteel after it is nearly finifhed. This is called cafe hardening. The following is among the receipts given for this purpofe:

Cafe hardening.

Cow's horn or hoof is to be baked, or thoroughly dried, and pulverized. To this add an equal quantity of bay falt. Mix them with ftale chamber ley, or white wine vinegar. Cover the iron with this mixture,

Procefs.

IRON.

ture, and bed it in the fame in loam, or inclofe it in an iron box. Lay it then on the hearth of the forge to dry and harden. Then put it in the fire, and blow till the lump have a red heat, and no higher, left the mixture be burned too much. Take the iron out, and immerfe it in water, to harden.

Comparifon of fteel and crude iron.

When we confider the operations by which crude iron is brought into the malleable ftate, then converted into fteel, and afterwards into a fufible metal, which is not malleable; we may perceive that fteel-making is a kind of inverfion of the procefs of refining iron, as practifed in the firft inftance. When the calx of iron is mixed together in the fmelting furnace, with combuftible matter and glafs, it will either be completely or partially revived, according to the management of the procefs. Much of the coal will however be fo enveloped with the vitreous matter as to remain unburned: and the reduced iron, with which it may be in contact, will be in the fame fituation as forged iron in the cementing pot; that is to fay, it will be in contact with coal at a very elevated temperature, and defended from the air. From the great infufibility of iron, it may reafonably be concluded that the reduced metal does not flow into the bottom of the furnace, until the charcoal has converted it into a fufible matter fimilar to fteel, by the fame action which takes place in cementation, whatever that action may be. Hence it muft follow, that the various fpecimens of crude or caft iron will differ in their qualities, as well on account of the degree of cementation they have undergone, as the degree of reduction which has taken place among the metallic

parts,

Page 327.

parts, which are carried down, and form the whole mafs. Since the coal, in the procefs of cementation, communicates or adds weight to the iron; and fince crude iron, as well as fteel, exhibits fparkles, and is more eafily burned than other iron; it may therefore be concluded that, in the procefs of refining, that part of the inflammable fubftance which had united with the metal is burned, and leaves the iron much lefs fufible than before. Stirring the mafs multiplies the contacts of the air with the burned fubftances; thefe furfaces of contact will therefore fucceffively afford thin coats of infufible metal. In this manner it is found, that if a large piece of crude iron be expofed to heat in a wind-furnace, the external part will be deprived of its fufibility during the time required to produce a ftrong heat in the whole mafs; and the internal part will be melted, and run out, leaving the fhell behind. Iron which is of the confiftence of pafte may therefore be confidered, like any other pafte, as a mixture of a fluid with a folid. It will be eafily underftood that the forging will bring the parts of difficult fufion together, and extrude the lefs refined and fluid parts: it will alfo be evident that this operation is not likely to drive out the whole of the fufible matter. When the iron has arrived at that ftate wherein the quantity of fibre or tough iron is fufficient to anfwer the mechanical purpofes to which it is intended to be applied, the artift will confider it as fufficiently refined; and the refidue of fufible iron contained in the bar anfwers, in all probability, the valuable purpofe of connecting thefe infufible maffes together. Thus we find that forged iron appears as if

Confideration of the effects of heat in refining iron.

Probable caufe of the property of welding.

if covered with a varnifh, when urged to a white heat; we find that this varnifh is more abundant in fteel; and that iron and fteel may be refpectively welded together by application in this ftate; an effect which it would be very difficult to account for, in this moft infufible of metals, if it were not for fuch an admixture. But caft fteel, fteel over-cemented, and crude iron, appear to be in the ftate of all other metals, platina excepted. They cannot be welded, becaufe welding implies a partial fufion; or an effect fimilar to the glueing or uniting of folids by the application of a fluid, which afterwards becomes confiftent. And if it be true that platina poffeffes this valuable property, it feems reafonable to infer that it muft alfo confift of two metallic fubftances of different degrees of fufibility.

Platina.

Crude iron and fteel.

Crude iron, and fteel of an uniform texture, confift therefore of a fufible combination of iron with the combuftible fubftance of the coal, or fomething which is imparted from it; the crude iron differing from the fteel fimply in being over-cemented, and lefs pure, on account of the admixture of metallic calx, which can fcarcely, perhaps, be avoided in the large procefs. It appears therefore that crude iron muft pafs through the ftate of fteel before it can become forged iron; and confequently that the fabrication of fteel from this laft is a circuitous procefs, which can only be repaid by the abfence of thofe unreduced parts which may exift in the crude iron. At fome forges, however, where the ore, the flux, the fuel, and the management, are adapted to each other, the produce affords fteel, when duly refined. At other manufactories,

Proceffes for refining crude iron, and making fteel in a direct way.

nufactories, the crude iron is either refined, or converted into ſteel, by running it into thin plates, which are ſtratified with charcoal, and burned in a cloſe furnace. In this way, the metal is refined by degrees, without undergoing fuſion; and if the heat be raiſed to that of cementation, the iron will not only be reduced, but converted into ſteel. In the forges of Carinthia the grey crude iron is alſo converted either into ſoft iron or ſteel, according to the management of a ſomewhat ſimilar proceſs. The iron is fuſed in a large melting pot; and a ſmall quantity of water being thrown upon the ſurface of the metal, cauſes a thin plate to congeal, which is taken off; and, by continuing the operation, the greateſt part of the fuſed iron becomes converted into plates. To produce ſteel, theſe plates are again fuſed, and kept a long time in an elevated heat; at the ſame time that the metal is defended from the contact of the air by a ſufficient quantity of the vitreous ſlag. To produce ſoft iron, the plates are expoſed to a continued roaſting, while the air is conſtantly renewed by means of two pair of bellows. The extenſive ſurface of the plates renders it unneceſſary to uſe that agitation, or ſtirring, which is required when fuſed crude iron is refined. In theſe proceſſes it is evident, that the ſame matter in the crude iron, which it obtained in the ſmelting furnace, is employed, and ſupplies the place of the charcoal of cementation in forming the ſteel; and, on the other hand, that this ſubſtance, which prevented the crude iron from being ſoft, tough, and infuſible, is burned away, together with a portion of the iron itſelf, while the remainder is left in a much purer ſtate.

Theſe

IRON.

The exiftence of plumbago in crude iron and fteel; afcertained in the dry way.

Thefe are the facts obferved at the furnaces. But the obfervations and inquiries of the chemift muft be carried farther, in order to determine what it is that iron gains or lofes at the time of its converfion into its various ftates. It is found that crude iron approaches towards the foft ftate, not only by heating with expofure to air, which burns the combuftible addition, but likewife by fufion, without the free accefs of air. In this cafe, when the fufion has been complete, and the cooling gradual, it is found that a black fubftance is thrown up to its furface, which is more abundant the greyer or blacker the iron; and the fame black fubftance is obferved to coat the ladles of forged iron, which are ufed to take out the metal, and pour it into moulds for cafting fhot and other articles. It appears therefore that the heated iron, like other heated fluids, is capable of holding a larger quantity of matter in folution than when cold; and that a portion of this black fubftance feparates during the cooling, whether by the gradual effect of furrounding bodies or by the contact of the ladle, in the fame manner as various falts are feparated, in part, from water by a diminution of temperature. From chemical analyfis, as well as from its obvious characters, this black fubftance is found to be plumbago, or the material ufed to make pencils, and commonly known by the name of black-lead.

Plumbago extricated from iron in the humid way.

The prefence of this black matter is likewife exhibited by diffolving fteel, or crude iron, in acids, in which plumbago is infoluble, and therefore remains behind in the form of a powder. Hence likewife is deduced the caufe of the black fpot which remains upon fteel, or crude iron, after its furface has been corroded

corroded by acids; for this ſpot conſiſts of the plumbago which remains after the iron has diſappeared by ſolution.

Quantities of plumbago, and of inflammable air, afforded by various kinds of iron.

Solution in the vitriolic or marine acids, not only exhibits the plumbago contained in iron, but likewiſe poſſeſſes the advantage of ſhewing the ſtate of its reduction by the quantity of inflammable air which is diſengaged: for whether this aërial fluid be ſupplied by the phlogiſton of the iron, or from the decompoſed water, it is agreed on all hands that its quantity, in like circumſtances, is proportional to that of the iron which is converted into calx. There are conſiderable differences between the various products of the ſmelting furnace in theſe reſpects; but it is found that the white crude iron affords the leaſt quantity of inflammable air in proportion to its bulk, and leaves a moderate portion of plumbago; the grey crude iron affords more inflammable air, and more plumbago, than the white; and the ſofteſt bar iron affords moſt inflammable air of any, and little or no plumbago. The quantities of inflammable air*, at a medium, by ounce meaſures, were 62, afforded by 100 grains of the white crude iron; 71 by the grey crude iron; and 77 by the malleable iron.

Degrees of reduction and cementation in iron.

Hence it may be inferred that, in the white crude iron, the proceſſes of reduction and cementation are both carried to a leſs extent than in the grey crude iron, which is produced by means of a ſtronger heat,

* Acad. Par. 1786, pages 166, 167. The numbers in the text are given as a rough meaſure; for, in fact, there can be no medium.

 excited

IRON.

excited with a larger quantity of fuel: and that the reduction of grey crude iron is ſtill leſs perfect than that of the ſoft bar iron; though this laſt, by the refining in an open veſſel, is ſo far from being more cemented, that it ſcarcely contains any plumbago at all.

Inaccuracies.

It muſt be admitted, however, that the ſolution in acids ſerves only to ſupport theſe general concluſions, in conjunction with the facts obſerved in the dry proceſſes; but cannot accurately ſhew either the quantities of inflammable air or plumbago afforded by the ſeveral kinds of iron. For the plumbago, as it becomes diſengaged, floats on the top of the vitriolic acid; where it gradually diſappears, though inſoluble in that acid. It muſt therefore be taken up by the inflammable air; and it is found that the volume of this air is diminiſhed by the abſorption. Hence there is a double ſource of inaccuracy from the loſs of plumbago, and the contraction of the inflammable air.

Plumbago.

As plumbago appears to be a compound of iron and combuſtible matter, and as the properties and effects of iron, in its various ſtates, cannot be well underſtood without a reference to thoſe of this ſubſtance, it will be expedient to give an account of it in this place, inſtead of referring it to the next ſection.

Characters of plumbago.

Plumbago, or black lead, is a well-known ſubſtance, of a black colour, and ſhining appearance, when cut. Its texture is rather ſcaly; but its fracture exhibits a granular and dull appearance. None of the ſpecimens have any conſiderable hardneſs. This mineral is found in England, Germany, France, Spain, and Africa; but the

IRON.

the fort beft adapted for making pencils comes chiefly from Borrowdale in Cumberland. For this purpofe, it is carefully fawed into narrow flips, or pieces, not more than one-tenth of an inch thick; which are glued between two half cylinders of cedar wood. An inferior kind of pencils is made by the Jews, by mixing the powder or faw-duft with gum arabic, or fufing it with refin or fulphur; and preffing or pouring it into the cavities of reeds. The powder of plumbago, with three times its weight of clay, and fome hair, makes an excellent coating for retorts; and the black lead or Heffian crucibles are compofed of the fame materials.

Habitudes.

Plumbago is not fubject to alteration by expofure to the action of air or water; and it is infoluble in acids. In clofed veffels it is either entirely, or nearly, unalterable by the ftrong heat of a furnace; but by continued ignition, and occafional ftirring in a fhallow veffel, under a muffle, it is gradually diffipated, or burned, leaving a refidue of calx of iron, of about one-tenth of the original weight. It detonates with nitre in a red heat; ten parts of this falt are required to one of plumbago before the whole will be decompofed, and exhibit no refidue of plumbago when the alkali is diffolved in water. The aërial product of this detonation is found to confift of a mixture of one-third fixed air; and the reft air which maintains combuftion: the alkali contains fixed air; and fome of the nitre is driven up by the heat. In order to fhew that the fixed air came from the plumbago, and not from the nitre, the firft analyfer * of this fubftance

Experiments tending to difcover the component parts of plumbago.

* Scheele. See his Effays, Eng. tranf. Effay xiii.

IRON.

detonated tin, antimony, and ſulphur, reſpectively, with nitre, and obtained no fixed air: and, ſtill more to place the inference beyond a doubt, he expoſed plumbago to diſtillation, with twice its weight of dry acid of arſenic: the acid was reduced to the ſtate of white calx and ſublimed; and pure fixed air came over. Similar reſults were had with the calces of mercury and lead; the metals were revived, and fixed air was expelled. When pulverized plumbago was diſtilled with cauſtic fixed alkali by a ſtrong heat, the volatile product was inflammable air; and the remaining alkali contained fixed air.

Phlogiſtic theory.

From theſe, and other facts, he concluded, that plumbago is a compound of phlogiſton and fixed air, with a little iron, which he ſuppoſed to be accidental. The exiſtence of the phlogiſton was judged to be proved by its detonation with nitre, as well as by the revival of the acid of arſenic and the metallic calces, and the extrication of inflammable air by alkali: he inferred the quantity of phlogiſton in this ſubſtance to be twice as much as in charcoal; becauſe it requires twice the quantity of nitre for its detonation. The preſence of fixed air was deduced from the aërial products in all the diſtillations but the laſt; and from the mild ſtate of the alkalis, in thoſe trials wherein they were uſed.

Antiphlogiſtic theory of plumbago.

The antiphlogiſtic philoſophers * conſider plumbago as a compound of iron and the acidifiable baſe of fixed air, which they call carbone, becauſe it exiſts moſt abundantly in charcoal. The difficulty of burn-

* Acad. Par. 1785, pag. 132, et ſeq.

ing

IRON.

ing or decompofing it, is confidered as a confequence of the combination of its parts, which are lefs difpofed to unite with vital air, than either would be if alone. The fame difficulty accounts for the large proportion of nitre required to deflagrate with it completely; a quantity required, not becaufe there is much combuftible matter to be burned, but becaufe a long continued and elevated heat is neceffary; by which means much of the nitre is decompofed, and its vital air flies off, without having been employed in the combuftion, as appears by the two thirds of the elaftic product, which will fupport the flame of a candle. The other facts are eafily adapted to this theory. By detonation with nitre it affords fixed air, becaufe the combuftible bafe is acidified by the vital air of the nitre. The arfenical acid, and metallic calces, are reduced by the abftraction of the vital air they contain; which vital air, combining with the acidifiable bafe contained in the plumbago, converts it into the fixed air, or acid, which flies off: And, laftly, in the diftillation of plumbago with humid alkali, a decompofition of the water takes place: its inflammable air flying off; and its vital air, combining with the acidifiable bafe, as before, forms fixed air, which unites with the alkali, and renders it mild.

Refemblance between plumbago and pyrites.

The chief difference in the matter of fact between thefe theorifts appears to confift in the iron; which the latter confider as a neceffary part of the combination; by means of which they account for its difficult combuftibility. Since plumbago does really contain iron, it may be confidered as a compound of a fimilar nature to the martial pyrites. Thus in the pyrites iron

IRON.

Page 151, 153.

is united to fulphur; which the phlogiftian philofophers affert to be a compound of vitriolic acid (or its bafe) and phlogifton, while their opponents take the fulphur to be a fimple fubftance, capable of acidification by the addition of vital air: and fo likewife plumbago is a compound of iron, united to another fubftance; which the phlogiftians affert to be fixed air, combined with phlogifton; at the fame time that the other party, rejecting the inflammable principle, affirm that it is the fimple acidifiable bafe, which will form fixed air when vital air is added to it. We fee therefore that it is the explanation, and not the facts, which forms the object of contention.

Recapitulation of the facts relating to the ftates of iron.

Since crude iron, then, contains the bafe of fixed air in combination, of which it may be deprived by heat with accefs of vital air, which converts it into the acid ftate; and fince it again recovers that bafe by cementation with charcoal, there can be no doubt but the plumbago is afforded by the fuel, it being highly probable that iron is neceffary to its feparate exiftence. It appears alfo that the reduction of the metallic calx takes place firft at a lower temperature; and that the combination of the bafe of fixed air follows at a greater heat. Whence, in the refining of iron, the plumbago is firft burned, and the iron remains reduced; and, in the cementation of bar iron, the metal is converted into fteel, with blifters on its furface; which moft probably arife from fixed air formed by the vital air of fome portions of unreduced calx, uniting with the acidifiable bafe from the charcoal. And, laftly, as iron holds this acidifiable bafe, or phlogifticated acid, in folution, fo likewife it may not be feparable from this

Refining.

Cementation.

me-

metallic folvent, without carrying a portion with it; in the fame manner as falts, which cryftallize in water, always take up part of the folvent in the formation of their cryftals. IRON.

Ufes of iron.

It would require many volumes to enumerate the leading ufes of iron. This moft valuable of metals is applied to fo many and fuch important ufes, that we cannot look round us without feeing its effects. When we contemplate the innumerable effects of human induftry, and afk ourfelves the fimple queftion, could this have been done without iron? there is not a fingle inftance which will not immediately fhew its value. It is indeed difficult to form a notion, how civilized fociety could exift without it.

CHAP. VIII.

CONCERNING TIN.

TIN.
Characters of tin.

TIN is a metal of a yellowifh white colour, confiderably harder than lead, fcarcely at all fonorous, very malleable, though not very tenacious. Wires cannot be made of it; but, under the hammer, it is extended into leaves called tin-foil, which are about one-thoufandth of an inch thick; and might eafily be beaten to lefs than half that thicknefs, if the purpofes of trade required it. The procefs for making tin-foil confifts fimply in hammering out a number of plates of this metal, laid together upon a fmooth block, or plate of iron. The fmalleft fheets are the thinneft. Its fpecific gravity is lefs than that of any other malleable metal. Long before ignition, it melts at about the 410th degree of Fahrenheit's thermometer; and, by a continuance of the heat, it is flowly converted into a white powder by calcination. Like lead, it is brittle when heated almoft to fufion; and exhibits a grained or fibrous texture, if broken by the blow of a hammer; it may alfo be granulated by agitation at the time of its tranfition from the fluid to the folid ftate. The calx of tin refifts fufion more ftrongly than that of any other metal; from which property, it is ufeful to form an opake white enamel, when mixed with pure glafs in fufion. The brightnefs of its furface, when fcraped, foon goes off by expofure to the air; but it

is

is not ſubject to ruſt, or corroſion, by expoſure to the weather.

Solution of tin in vitriolic acid:

Concentrated vitriolic acid, aſſiſted by heat, diſſolves half its weight of tin, at the ſame time that vitriolic acid air eſcapes in great plenty. By the addition of water a calx of tin is precipitated. Vitriolic acid, ſlightly diluted, likewiſe acts upon this metal; but if much water be preſent, the ſolution does not take place. In the vitriolic ſolution of tin there is an actual formation, or extrication, of ſulphur, which renders the fluid of a brown colour whilſt it continues heated, but ſubſides by cooling. The tin is likewiſe precipitated in the form of a white calx by a continuance of the heat, or by long ſtanding without heat. This ſolution affords needle-formed cryſtals by cooling.

—in nitrous acid.

Nitrous acid and tin combine together very rapidly, without the aſſiſtance of heat. Moſt of the metal falls down in the form of a white calx, extremely difficult of reduction; and the ſmall portion of tin which remains ſuſpended, does not afford cryſtals, but falls down, for the moſt part, upon the application of heat, to inſpiſſate the fluid. The ſtrong action of the nitrous acid upon tin produces a ſingular phenomenon, which is happily accounted for by the modern diſcoveries in chemiſtry. Mr. De Morveau * has obſerved that, in a ſolution of tin by the nitrous acid, no elaſtic fluid was diſengaged; but that volatile alkali was formed. This alkali muſt have been produced by the phlogiſticated air of that part of the nitrous acid

Singular effect.

* Kirwan on Phlogiſton, 2d edition, p. 234.

which

TIN.

Volatile alkali produced from nitrous acid, &c.

which was employed in affording pure air to calcine the tin. The phlogisticated air must therefore have combined with inflammable air: but whether this inflammable air was afforded by a decomposition of the water of the menstruum, or whether it came from the phlogiston of the tin, is a question that must remain undetermined until decisive experiments have been made for the establishment of one or the other of the two theories, which at present divide the chemical world.

Solution of tin in marine acid:

The marine acid dissolves tin very readily, at the same time that it becomes of a darker colour, and ceases to emit fumes. A slight effervescence takes place with the disengagement of a fetid inflammable gas. Marine acid suspends half its weight of tin, and does not let it fall by repose. It affords permanent crystals by evaporation. If the tin contain arsenic, it remains undissolved at the bottom of the fluid.

—in dephlogisticated marine acid:

Dephlogisticated marine acid dissolves tin very readily, and without sensible effervescence. The solution itself does not appear to differ from the foregoing.

—in aqua regia.

Aqua regia, consisting of two parts nitrous and one marine acid, combines with tin with effervescence, and the development of much heat. In order to obtain a permanent solution of tin in this acid, it is necessary to add the metal by small portions at a time; so that the one portion may be entirely dissolved before the next piece is added. Aqua regia, in this manner, dissolves half its weight of tin. The solution is of a reddish brown, and in many instances assumes the form of a concrete gelatinous substance. The addition of water sometimes produces the concrete form in this folution, which is then of an opal colour, on account of the calx of tin diffufed through its fubftance. The uncertainty attending thefe experiments with the folution of tin in aqua regia feems to depend upon the want of a fufficient degree of accuracy in afcertaining the fpecific gravities of the two acids which are mixed; the quantities of each, and of the tin, together with that of the water added. It is probable that the fpontaneous affumption of the concrete ftate depends upon water imbibed from the atmofphere. The folution of tin in aqua regia is ufed by dyers to heighten the colours of cochineal, gum lac, and fome other red tinctures, from crimfon to a bright fcarlet, in the dyeing of woollens.

TIN. Solution of tin in aqua regia.

M. Hermftædt has fucceeded in the actual acidification of this metal, by treating it with the marine and nitrous acids. He diffolves pure tin in pure marine acid, and boils this folution with nitrous acid (diftilled from manganefe) until the red vapours ceafe to appear. The fluid, which is then limpid, is expofed to diftillation until the whole of the marine and nitrous acids have been diffipated. The white remaining mafs is foluble in three parts of water, and is the acid of tin. A red heat converts this matter into a yellow tranfparent fubftance, neither acid nor foluble in water; but it regains both properties by a few weeks expofure to the air*.

Acid of tin.

The acetous acid fcarcely acts upon tin. The operation of other acids upon this metal has been little inquired into.

* Journal de Phyf. xxxv. 391. Nov. 1789.

When

TIN.

The fuming liquor of Libavius.

When equal parts of an amalgam of tin and mercury, and of corrofive fublimate, are triturated together, and the mixture expofed to diftillation in a retort, by a very gentle heat; a colourlefs fluid firft comes over, which is followed by a thick white fume, which becomes condenfed into a tranfparent liquor, called the fuming liquor of Libavius, on account of the copious fumes it emits when the veffel that contains it is opened On account of the confiderable volatility of this liquid, it rifes, partly in the form of flowers, to the top of the bottle in which it is put; fo that, in the courfe of feveral months, it becomes entirely clofed. The compofition and effects of this liquid were but imperfectly known until lately, when Mr. Adet made feveral ingenious experiments upon it. By expofing this liquid under receivers containing dry air, over mercury, he found that the volatile fluid arofe, and lined the veffel with cryftals, when water was prefent; though very few cryftals were formed when the air was as dry as it could be made. He obferved likewife, that when water was added to the fuming liquor of Libavius, it became folid, and ceafed to emit fumes. A precife quantity of water is required to produce this effect in the moft perfect manner. If the quantity of water be too fmall, the liquor retains more or lefs of its difpofition for the fluid ftate; and if it be too confiderable, the fluidity of the water prevails. By feveral trials he found that the due proportion of water to be added to the fuming liquor of Libavius was as 7 to 22. A kind of ebullition, or efcape of bubbles, was produced during the combination; which, on examination, was found to arife from the

Adet's examination of the fuming liquor of Libavius.

TIN.

Adet's examination of the fuming liquor of Libavius.

the efcape of the air previoufly contained in the fluid water. He found likewife that this concrete fubftance, when rendered fluid by an increafe of temperature, was capable of diffolving more tin, without the difengagement of inflammable air. After the concrete fubftance was faturated with tin, it could no longer be fublimed, but might be made to undergo a red heat; during which time there was an efcape of vapours, confifting of tin combined with the marine acid; and, after a ftrong heat, the refidue was a white calx of tin. It appeared therefore that the liquor of Libavius, rendered concrete by water, and faturated with tin, refembles in its properties the common folution of tin in the marine acid.

From thefe circumftances, Mr. Adet concludes that the tin, by ftronger affinity, combines with the aërated or dephlogifticated marine acid of the corrofive fublimate with which it is heated; that this combination contains no water; and that, as it abounds with a fubftance of fuch extreme volatility as that aërated acid, its freezing point is very low, infomuch that it is habitually fluid; that the addition of water, in a due proportion, alters the freezing point, and renders it concrete at a common temperature; and, laftly, that the ftate of the marine acid in this fubftance is that which is called aërated, or dephlogifticated; which is proved, as well from the experiments which afcertain that ftate in corrofive fublimate, as from fimilar experiments with the fuming liquor, which, as has been obferved, is capable of diffolving more tin without difengaging inflammable air. The fuming liquor of Libavius has therefore the fame relation to the common

TIN. mon folution of tin as corrofive fublimate has to calomel*.

The refidue, after the diftillation by which the fuming liquor of Libavius is produced, confifts of tin combined with the marine acid, calomel, and running mercury, which fublime into the roof and neck of the retort; and at the bottom is found an amalgam of mercury and tin, covered with a faline combination of marine acid with tin, and fuch other metals as the tin may have been adulterated with. Much information may be derived from the foregoing experiments of Mr. Adet refpecting the phenomena produced when tin is diffolved in aqua regia.

Habitudes of tin, with earths and neutral falts:

Earthy fubftances do not appear to affect this metal in the dry way. It detonates very rapidly with nitre, and becomes converted into a calx, which partly combines with the alkali. All the vitriolic falts are decompofed by tin. The tin becomes calcined, and the vitriolic acid converted into fulphur, either by the phlogifton of the metal, according to the ancient theory; or by the fubtraction of its vital air, according to the modern theory. This fulphur appears to combine with the alkali, or earth of the falt, with which it forms an hepar that diffolves part of the calx.

—with fal ammoniac.

Sal ammoniac is very readily decompofed by tin. Alkaline and inflammable air are difengaged; and a concrete marine falt remains behind, which, in fome meafure, refembles the fuming liquor of Libavius. The volatile alkali, or alkaline air, which efcapes, is

* Annales de Chimie, i. 1, &c.

difen-

difengaged by virtue of the fuperior affinity of the calx of tin with the marine acid, at the temperature of the experiment. The inflammable air, which likewife flies off, is a confequence of the calcination of the tin; and will be derived either from the phlogifton of the tin, or the decompofition of the water, according to the theory which may be applied in the explanation. Notwithftanding the facility with which this metal decompofes fal ammoniac, there is an inconvenience refulting from its ufe, which depends on the great fufibility of this metal; in confequence of which, it cannot be intimately mixed with the fal ammoniac, but remains at the bottom of the veffel in the fluid ftate; while part of the fal ammoniac eludes its action, and is fublimed entire.

Spontaneous decompofition and inflammation of metallic falts.

If the cryftals of the faline combination of copper with the nitrous acid be grofsly powdered, moiftened, and rolled up in tin-foil, the falt deliquefces, nitrous fumes are emitted, the mafs becomes hot, and fuddenly takes fire. In this experiment* the rapid tranfition of the nitrous acid to the tin is fuppofed to produce or develop heat enough to fet fire to the nitrous falts; but by what particular changes of capacity, has not been fhewn.

Combination of tin with fulphur.

If fulphur, in powder, be added to about five times its weight of melted tin, the two fubftances combine, and form a black compound, which takes fire, and is much lefs eafily fufed than the tin itfelf. The mafs is brittle, and of a needled texture.

Aurum mufivum.

The combination of tin and fulphur, called aurum

* Of Dr. Higgins. Philof. Tranf. lxiii. p. 137.

mufivum,

TIN.

Aurum musivum.

musivum, is thus made: Melt twelve ounces of tin, and add to it three ounces of mercury; triturate this amalgam with seven ounces of sulphur, and three of sal ammoniac. Put the powder into a matrass, bedded rather deep in sand, and keep it for several hours in a gentle heat; which is afterwards to be raised, and continued for several hours longer. If the heat has been moderate, and not continued too long, the golden-coloured scaly porous mass, called aurum musivum, will be found at the bottom of the vessel; but, if it has been too strong, the aurum musivum fuses to a black mass of a striated texture. This process is thus explained: As the heat increases, the tin, by stronger affinity, seizes, and combines with, the marine acid of the sal ammoniac; while the alkali of that salt, combining with a portion of the sulphur, flies off in the form of an hepar. The combination of tin and marine acid sublimes, and is found adhering to the sides of the matrass. The mercury, which served to divide the tin, combines with part of the sulphur, and forms cinnabar, which also sublimes; and the remaining sulphur, with the remaining tin, forms the aurum musivum, which occupies the lower part of the vessel. It must be admitted, however, that this explanation does not indicate the reasons why such an indirect and complicated process should be required to form a simple combination of tin and sulphur.

Combination of tin with phosphorus.

When tin is heated with phosphoric acid and charcoal, the metal appears to be very little changed. A combination, however, seems to take place; for the phosphorus burns on the surface of the metal when heated by the blow-pipe.

Tin

TIN.

Metallic mixtures.

Tin unites with bifmuth by fufion ; and becomes harder and more brittle, in proportion to the quantity of femi-metal added. With nickel it forms a white brilliant mafs. It cannot eafily be united in the direct way with arfenic, on account of the volatility of this femi-metal ; but, by heating it with the combination of the arfenical acid and vegetable alkali, the falt is partly decompofed ; and the tin, combining with the acid, becomes converted into a brilliant brittle compound, of a plated texture. It is thought that all tin contains arfenic ; and that the crackling noife which is heard upon bending pieces of tin is produced by this impurity. Cobalt unites with tin by fufion ; and forms a grained mixture, of a colour flightly inclining to violet. Zinc unites very well with tin, increafing its hardnefs, and diminifhing its ductility, in proportion as the quantity of zinc is greater. This is one of the principal additions ufed in making pewter, which confifts, for the moft part, of tin. The beft pewter does not contain above one-twentieth part of admixture, which confifts of zinc, copper, bifmuth, or fuch other metallic fubftances as experience has fhewn to be moft conducive to the improvement of its hardnefs and colour. The inferior forts of pewter, more efpecially thofe ufed abroad, contain much lead, have a blueifh colour, and are foft. The tin ufually met with in commerce in this country has no admixture to impair its purity, except fuch as may accidentally elude the workmen at the mines. But the tin met with in foreign countries is fo much debafed by the dealers in that article, efpecially the Dutch, that pewter and tin are confidered

Pewter.

Miftake of foreigners refpecting Englifh tin.

TIN.

abroad as the fame fubftance. Regulus of antimony forms a very brittle, hard, mixture with tin; the fpecific gravity of which is lefs than would have been deduced by computation from the fpecific gravities and quantities of each, feparately taken. Wolfram, fufed with twice its weight of tin, affords a brown fpungy calx, which is fomewhat ductile.

Native tin.

Tin is fcarcely ever found native. Native tin may be analyfed, in the moift way, by the application of nitrous acid, which calcines the tin, and diffolves the other metals it may contain. One hundred and forty grains of the wafhed and dried calx are equivalent to one hundred grains of metallic tin. The metallic admixtures may be feparated from the nitrous acid by methods adapted to their refpective properties; which may be eafily gathered from what has already been obferved in the humid analyfis of the metals before treated of.

Calciform ores of tin.

The calciform ores of tin are—tin fpar, which is generally of a whitifh or grey colour, fometimes greenifh or yellowifh, femi-tranfparent, and cryftallized in a pyramidical form, or irregularly—opake brown or black tin ore, cryftallized, and embodied in quartz, fluor, or mica, or mixed with white and yellow pyrites; thefe ores contain a mixture of iron—the reddifh yellow, or garnet ore, which contains more of iron than of tin—and the tin ftone, vulgarly called loadftones, which contain ftill lefs tin.

Tin ores containing arfenic;

It was formerly fuppofed that tin was frequently mineralized by arfenic; but it is now admitted that the arfenic, which may be contained in tin, is afforded by the matrix. The fcarcity of fulphureous tin ores was

and fulphur.

was likewife confidered, till lately, as a very fingular fact, on account of the facility with which that fubftance unites to tin: fuch combinations, however, have fince been found. The native aurum mufivum, from Siberia, is of this kind: and a very confiderable vein of tin in combination with fulphur, and an admixture of copper and iron, has been found in Cornwall *. The analyfis of tin ores in the humid way is an object of fome difficulty; becaufe they are not acted upon effectually either by the vitriolic, nitrous, or marine acids, or by aqua regia. The method of Bergman is as follows: The ore muft be reduced to a very fubtile powder by levigation and elutriation. This laft procefs confifts in agitating any powder in water, which is heavy enough to fink in that fluid. The particles will be refifted in their defcent, according to the furfaces they oppofe againft the fluid. It is fcarcely neceffary to obferve, that a larger body prefents a lefs furface to be refifted, than the fame body would oppofe if it were divided into parts. For this reafon, when a powder, confifting of particles of the fame denfity, but different magnitudes, is agitated in a flighter fluid, the largeft pieces come firft to the bottom: and hence the method of elutriation enables us to affort the various particles of a powder according to their magnitudes, by firft agitating the fluid, and fucceffively decanting it into different veffels. Thus, for example, if the water be decanted five feconds after the agitation, it will leave a powder behind it; if it

Procefs of elutriation defcribed and explained.

* See Magellan's Cronftedt, p. 637. The contents of one pecimen were 30 parts fulphur, 41 tin, 43 copper, 2 iron, and ftony matrix.

be

TIN.

be again decanted, at the end of five feconds more, the fecond veffel will contain a much finer powder than the foregoing; and, by a third decantation, a ftill more fubtile powder will be obtained. This is the method applied in the preparation of the white calx of tin called putty, and ufed for polifhing fine metallic fpeculums, and the object lenfes of telefcopes; and in this way the tin ore, to be analyfed, may be reduced to a very fubtile powder, by levigating and again wafhing the coarfe refidue which fubfides in the firft veffel. It may be obferved, that the fucceffive decantations are unneceffary where the very fineft powder only is wanting; becaufe this may be as well obtained by fuffering the water to ftand a fufficient time before it is decanted off at firft. To the very fubtile powder of tin ore thus afforded, a quantity of concentrated vitriolic acid muft be added, and kept in a ftrong digefting heat for feveral hours. A fmall portion of concentrated marine acid muft be poured into this when cold. A ftrong effervefcence takes place, with confiderable heat, and the efcape of marine acid air, which has been deprived of its water by the vitriolic acid. After the expiration of an hour or two, fome water muft be added, and the clear liquor decanted. The fame operation muft be repeated with the refiduum, until the acids can diffolve no more: and nothing will then remain but the ftony matrix. The folution, when precipitated by means of mild alkali, will afford 100 grains of metallic tin for each 132 grains of precipitate, when wafhed and dried. If the precipitate do not confift of pure tin, but contain copper or iron, it muft be calcined for an hour in

Putty.

Analyfis of tin ores, in the humid way:

in a red heat; then digefted in nitrous acid, which will take up the copper; and afterwards in marine acid, which will diffolve the iron.

In the dry way, after pulverization, and feparation of the ftony matter by wafhing, the tin ores may be haftily fufed with twice their weight of a mixture of pitch and calcined borax, in a crucible lined with charcoal, and covered; or the ore may be mixed with twice its weight of tartar, one part of black flux, and half a part of refin. This mixture being then divided into three parts, each part muft be fucceffively projected into a crucible ignited to whitenefs, which muft be immediately covered as foon as the portion thrown in ceafes to flame. —in the dry way.

The operation of reducing tin ores in the large way, is conducted upon fimilar principles. When impure, they are cleanfed from foreign admixtures, by forting, pounding, and wafhing. A flight previous roafting renders the ftony parts more friable; and, when arfenic is contained in the matrix, it is driven off by a ftrong heat, continued for a fhort time; the ore being frequently ftirred, to prevent its running together by fufion. In the fmelting of the ore, care is taken to add a larger quantity of fuel than is ufual in the reviving of other metals; and to avoid a greater heat than is neceffary to reduce the ore, in order that the lofs by calcination may be prevented as much as poffible. Reduction of tin in the large way.

Tin is a metal which, as far as our prefent information extends, is not very much diffufed. It is found in Bohemia and Saxony, and on the ifland of Malacca in the Eaft-Indies. But the largeft quanti- Countries which afford tin.

 ties.

TIN. ties, at leaſt for the European conſumption, are found in England, particularly in the county of Cornwall. This iſland has been famous for its tin mines from the remoteſt periods of hiſtory; and would not, probably, have been frequented by the ancient Phœnician navigators, if they had not been attracted hither by the great plenty of tin with which it abounds. Several etymologiſts have endeavoured to ſhew that the name of Britain is derived from a word common to the Syrian and Chaldean languages, denoting tin; but on this no great ſtreſs can be laid.

Uſes. The uſes of tin are very numerous, and ſo well known, that they ſcarcely need be pointed out. Several of them have already been mentioned. The tinning of iron and copper, the ſilvering of looking-glaſſes, and the fabrication of a great variety of veſſels and utenſils for domeſtic and other uſes, are among the advantages derived from this metal.

CHAP.

CHAP. IX.

CONCERNING BISMUTH.

BISMUTH is a ſemi-metal, of a yellowiſh or reddiſh-white colour, little ſubject to change in the air. It is ſomewhat harder than lead, and is ſcarcely, if at all, malleable; being eaſily broken, and even reduced to powder by the hammer. The internal face, or place of fracture, exhibits large ſhining plates, diſpoſed in a variety of poſitions: thin pieces are conſiderably ſonorous. At a temperature not exceeding the 460th degree of Fahrenheit it melts; and its ſurface becomes covered with a greeniſh, grey, or brown calx. A ſtronger heat ignites it, and cauſes it to burn with a ſmall blue flame; at the ſame time that a yellowiſh calx, known by the name of flowers of biſmuth, is driven up. This calx appears to riſe in conſequence of the combuſtion; for it is very fixed, and runs into a greeniſh glaſs when expoſed to heat alone. Biſmuth, urged by a ſtrong heat, in a cloſed veſſel, ſublimes entire. This ſemi-metal cryſtallizes very diſtinctly, when gradually cooled. BISMUTH. Characters of biſmuth.

The vitriolic acid has a ſlight action upon biſmuth, when it is concentrated, and boiling. Vitriolic acid air is exhaled, and part of the biſmuth is converted into a white calx. A ſmall portion combines with the vitriolic acid, and affords a deliqueſcent ſalt in the form of ſmall needles. Action of vitriolic acid.

BISMUTH.

Solution in nitrous acid.

The nitrous acid attacks bifmuth with the greateft rapidity and violence; at the fame time that much heat is extricated, and a large quantity of nitrous air efcapes. The folution, when faturated, affords cryftals as it cools; the falt detonates weakly, and leaves a yellow calx behind, which efflorefces in the air. Upon diffolving this falt in water, it renders that fluid of a milky white, and lets fall a calx of the fame colour.

White calx, or magiftery of bifmuth.

The nitrous folution of bifmuth exhibits the fame property when diluted with water; moft of the metal falling down in the form of a white calx, called magiftery of bifmuth. This precipitation of the nitrous folution, by the addition of water, is the criterion by which bifmuth is diftinguifhed from all other metals. The magiftery, or calx, is a very white and fubtile powder, when prepared by the addition of a large quantity of water: it is ufed as a paint for the complexion, and is thought gradually to impair the fkin. The liberal ufe of any paint for the fkin feems, indeed, likely to do this; but there is reafon to fufpect, from the refemblance between the general properties of lead and bifmuth, that the calx of this femi-metal may be attended with noxious effects fimilar to thofe which the calces of lead are known to produce.

Solution in marine acid.

The marine acid does not readily act upon bifmuth. It is neceffary that the acid fhould be concentrated, and kept a long time in digeftion upon it; or that it fhould be diftilled from the femi-metal. The refidue when wafhed with water, affords a faline combination, which does not eafily cryftallize, but may be

7 fub-

ſublimed in the form of a ſoft fuſible ſalt, called butter of biſmuth. The marine ſolution of biſmuth likewiſe affords a precipitate of calx by the addition of water. Marine acid ſeizes the calx of biſmuth, when added to its ſolution in nitrous acid; and forms a compound of ſparing ſolubility, which falls to the bottom. Alkalis likewiſe precipitate its calx; but not of ſo beautiful a white colour as that afforded by the affuſion of pure water.

Habitudes of biſmuth with earths, ſalts, ſulphur:

The effects of earths and alkalis upon biſmuth, in the dry way, have been little attended to. Nitre calcines it, with ſcarcely any perceptible detonation. Sal ammoniac is not decompoſed by biſmuth in the metallic ſtate, though its calx readily combines with the marine acid of that ſalt, and diſengages the volatile alkali. Sulphur unites with biſmuth by fuſion, and forms a blueiſh grey brilliant maſs, of a needle-formed texture.

—and metallic ſubſtances.

This ſemi-metal unites with moſt metallic ſubſtances; and renders them, in general, more fuſible. When calcined with the imperfect metals, its glaſs diſſolves them, and produces the ſame effect as lead in cupellation; in which proceſs, it is even ſaid to be preferable to lead.

Uſes.

Biſmuth is uſed in the compoſitions of pewter, in the fabrication of printers types, and in various other metallic mixtures.

Native biſmuth and its ores.

It is ſometimes found native, and may be analyſed, in the humid way, by ſolution in nitrous acid, and precipitation, by the addition of water; which throws down 113 grains of calx for every 100 of metallic biſmuth. It is likewiſe found in the calciform ſtate;

and

BISMUTH.

and mineralized by ſulphur, of a grey colour, reſembling galena, but heavier. Theſe ores may alſo be analyſed by nitrous acid, like the foregoing.

Reduction of biſmuth ores.

Biſmuth is eaſily ſeparable, in the dry way, from its ores, on account of its great fuſibility. It is uſual, in the proceſſes at large, to throw the biſmuth ore into a fire of wood; beneath which a hole is made in the ground to receive the metal, and defend it from calcination. The ſame proceſs may be imitated in the ſmall way, in the examination of the ores of this metal; nothing more being neceſſary than to expoſe it to a moderate heat in a crucible, with a quantity of reducing flux; taking care, at the ſame time, to perform the operation as ſpeedily as poſſible, that the biſmuth may be neither calcined nor volatilized.

CHAP.

CHAP. X.

CONCERNING NICKEL.

NICKEL. Characters.

NICKEL is a reddiſh-white metallic ſubſtance, of great hardneſs, and of an uniform texture; very difficult to be purified, and always magnetical, whence it has been ſuppoſed to contain iron in its pureſt ſtate. It is malleable, and is ſcarcely more fuſible than pure iron. Its calces are of a green colour.

Treatment of the ores of nickel.

This metallic ſubſtance has not been applied to any uſe: and the chief attention of thoſe chemiſts who have examined it has been directed to obtain it in a ſtate of purity; which, however, has not yet been accompliſhed. It is found either native or calciform; but moſt commonly mineralized in combination with arſenic, ſulphur, cobalt, and iron, in the ore called kupfer nickel, or falſe copper. This is of a reddiſh yellow, or coppery colour; of a texture either uniform, granular, or ſcaly; bright in its fracture, and almoſt always covered with a green efflorefcence of calx. Moſt of the ſulphur and arſenic may be driven off by long-continued roaſting, and the occaſional addition of charcoal, which prevents the arſenic from being rendered more fixed by calcination; and the green calx which remains may be fuſed by the ſtrongeſt heat of a ſmith's forge, together with two or three times its weight of black flux. The regulus thus obtained is

of

NICKEL. of a reddiſh-white colour, and brittle; but is very far from being pure. Repeated calcinations for many hours, and reductions, ſcarcely deprive the regulus of iron; and it is ſtill highly magnetic, when purified to ſuch a degree as to poſſeſs conſiderable malleability. Combination with ſulphur, with liver of ſulphur, detonation with nitre, and ſolution in the volatile alkali and vitriolic acid, did not deprive it of its magnetiſm.

Pureſt regulus of nickel: When the regulus *, obtained by ſcorification and reduction, was combined with ſulphur, and reduced again after the diſſipation of the ſulphur by ſtrong heat, and the addition of charcoal, to promote the volatility of the arſenical contents; and this proceſs was three times repeated; the reduced metal was ſo infuſible, as not to run into a maſs by the ſtrongeſt heat of a ſmith's forge, continued for three quarters of an hour. Its colour was then whitiſh, mixed with a glittering kind of red; it was ſtrongly magnetical; of a ſpecific gravity of 8.66; and a globule of one line in diameter was extended by the hammer into a plate of upwards of three lines in diameter: ſo that it is, —is an entire metal. properly ſpeaking, an entire metal, and not a ſemi-metal. It afforded a blue ſolution with the volatile alkali; and in nitrous acid its ſolution was of a full green.

Action of vitriolic acid. Concentrated vitriolic acid acts upon the regulus of nickel, and corrodes it. The reſidue, after diſtillation of the acid, is a greyiſh powder; part of which is in the ſaline ſtate, and affords green cryſtals by ſolution in water and evaporation.

* Bergman on Nickel, in vol. ii. of his Eſſays.

The

NICKEL.

The nitrous folution of this metal affords faline cryftals. Alkalis precipitate it, and rediffolve the precipitate. Nitre detonates with nickel in the dry way. Sulphur readily combines with it by fufion, as does likewife arfenic; and both adhere very pertinacioufly to it, as has been already fhewn.

Whether nickel be truly a peculiar metal.

Nickel has been thought to be a modification of iron. This conclufion is grounded chiefly on its magnetifm, and the confideration of the very remarkable and different properties iron is known to be capable of affuming, in its feveral ftates. Others have fuppofed it to be an alloy of copper with various metallic admixtures. The blue colour it affords with volatile alkali, is the chief circumftance which gave rife to this opinion. But it has been very properly obferved *, that many of the known metals would fcarcely have endured more fevere trials than this fubftance has undergone, without fhewing indications, at leaft as ftrong, againft the fuppofition of their being diftinct bodies, as any afforded by nickel; and confequently, that fo long as no one is able to produce this metal from pure iron or copper, and to explain in an intelligible way the procefs by which it can be generated, we muft continue to regard it as a peculiar fubftance, poffeffing diftinct properties. The general opinions of chemifts concur in admitting the force of this reafoning.

* Bergman, ii. 264.

CHAP.

CHAP. XI.

CONCERNING ARSENIC.

ARSENIC. Characters.

ARSENIC in the metallic ſtate, or the regulus of arſenic, is of a bright yellowiſh white colour, ſubject to tarniſh, and grow black, by expoſure to air. It is brittle, and when broken exhibits a laminated texture. In cloſe veſſels it ſublimes entire; but burns with a ſmall flame, if reſpirable air be preſent.

White calx of arſenic:

The arſenic met with in commerce has the form of a white calx. It is brought chiefly from the cobalt works in Saxony, where zaffre is made. Cobalt ores contain much arſenic, which is driven off by long torrefaction. The ore is thrown into a furnace reſembling a baker's oven, with a flue, or horizontal chimney, nearly two hundred yards long; into which the fumes paſs, and are condenſed into a greyiſh or blackiſh powder. This is refined by a ſecond ſublimation in cloſe veſſels, with a little pot-aſh, to detain the impurities. As the heat is conſiderable, it melts the ſublimed flowers into thoſe cryſtalline maſſes which are met with in commerce.

—is in a ſaline ſtate.

The calx of arſenic is ſo far in the ſaline ſtate, as to be ſoluble in about eighty times its weight of water at the temperature of 60°, or in fifteen times its weight of boiling water.

Regulus.

The regulus may be obtained from this calx, either by quickly fuſing it together with twice its weight of ſoft ſoap, and an equal quantity of alkali, and pouring it

Regulus.

it out, when fused, into an hot iron cone; or by mixing it in powder with oil, and exposing it in a matrass to a sand heat. This process is too offensive to be made but in the open air, or where a current of air carries off the fumes. The decomposed oil first rises; and the regulus is afterwards sublimed, in the form of a flaky metalline substance.

Action of vitriolic acid:

Vitriolic acid does not attack the regulus of arsenic, nor its calx, when cold; but, if it be boiled upon this semi-metal, vitriolic acid air is emitted, a small quantity of sulphur sublimes, and the arsenic is reduced to the calciform state. Boiling vitriolic acid dissolves the calx of arsenic; but scarcely retains any portion of it when cold. The calx of arsenic is considerably less volatile when vitriolic acid is present, or mixed with it; but it is said that washing deprives it of the acid, and restores its properties.

—of nitrous acid:

Nitrous acid readily attacks and calcines the regulus of arsenic: it likewise dissolves the calx of this semi-metal, in considerable quantity, by the assistance of heat; and affords a crystallized deliquescent salt by evaporation, which does not detonate on red-hot coals. The calx of arsenic is acidified by the action of nitrous acid distilled from it.

—of marine acid:

Boiling marine acid dissolves the regulus, and also the calx of arsenic; but affects it very little when cold. This solution affords precipitates upon the addition of alkalis.

—of aerated acid.

The dephlogisticated or aërated marine acid converts the calx of arsenic into arsenical acid.

The calx of arsenic acts, in many instances, like an acid. It decomposes nitre by distillation; the nitrous

acid

ARSENIC.

acid flying off, and the arsenical salt of Macquer remaining behind. In this process, the nitrous acid appears to acidify the calx. Quadrangular nitre is affected in the same manner. When the white calx of arsenic is distilled with sulphur, volatile vitriolic acid flies off, and a combination of a yellow colour, called orpiment, is produced; which appears to consist of sulphur, united to regulus of arsenic; that is to say, part of the sulphur receives vital air from the calx; to which, according to the ancient system, it communicates phlogiston: and in this manner the sulphur becomes converted into vitriolic acid; while the arsenical calx is reduced, and combines with the rest of the sulphur. The combination of sulphur and arsenic which has been fused, is of a red colour; and known by the name of realgal, or realgar. Realgar appears to be less volatile than orpiment, or the yellow combination; for it remains at the bottom, while the other sublimes; but in what respect they differ from each other has not been well ascertained. It is not improbable but that the orpiment may contain the calx in a more reduced state than the realgar. A strong heat converts orpiment into realgar.

Distillation of calx of arsenic with sulphur.

Orpiment and realgar.

Liver of sulphur.

Saline liver of sulphur dissolves the calx of arsenic; but more readily attacks the regulus.

Fixed alkalis.

Watery solutions of fixed alkalis dissolve the calx of arsenic; and, if they be loaded with it by means of heat, a brown tenacious mass is produced, which acquires solidity, has a disagreeable smell, and is called hepar of arsenic. Mineral acids precipitate part of the arsenic; but a portion of it, being acidified, adheres more tenaciously to the alkali. The acids occasion

ſion no precipitation from the ſolution of arſenic in the volatile alkali. It is not eaſy to explain what happens in this caſe, without further experiments. The ſolutions of calx of arſenic in alkalis differ much in their properties from the combination which is produced when the nitrous ſalts are decompoſed by its means. This difference is accounted for from the conſideration that it is the calx of arſenic in the firſt caſe, and the acid in the latter, which combines with the alkalis.

ARSENIC.

Combination of calx of arſenic, with alkalis:

A ſolution of the calx of arſenic acts upon metals in the humid way, moſt probably in conſequence of its approach to the acid ſtate.

—with metals.

The acid of arſenic being applied to the filings of the metals, in a long-necked flaſk, to prevent its reduction, acts upon ſeveral of the metals in a digeſting heat. Gold and platina are ſcarcely acted upon. Silver is not attacked by digeſtion; but when the acid comes to be fuſed, the metal is diſſolved, and affords a colourleſs glaſs, which is nearly tranſparent; ſoluble in water, with the loſs of greateſt part of the ſilver, which ſubſides in the form of a brown powder, containing a minute portion of the acid; and reducible, like the other precipitates of ſilver, by mere heat. Mercury is not attacked by the arſenical acid, in the heat of digeſtion; but when the acid and mercury are urged in a retort, by an heat which is near melting the veſſel, part of the mercury combines with the acid, and forms a yellowiſh maſs of extremely difficult fuſion; very fixed, and inſoluble in water. Diluted nitrous and vitriolic acids have ſcarcely any effect on it, but marine acid readily diſſolves it. This ſolution, by evaporation to dryneſs, and diſtillation, affords

Action of arſenical acid—

—on gold, platina:

—ſilver:

—mercury.

 corro-

ARSENIC.

Action of arsenical acid on copper:

corrofive fublimate, and the refidue is arfenical acid: whence it follows, that the mercury in the arfenical combination muft have been perfectly calcined. Copper is diffolved by the arfenical acid in digeftion, and affords a green folution. One part of copper filings, mixed with two of dry arfenical acid, affords a blue mafs by fufion, at an elevated degree of heat, which is foluble in water; and then proves to be the fame combination as was produced by digeftion. The watery folution lets fall a light blue powdery matter, confifting of a combination of copper with arfenical acid. Iron likewife is attacked by this acid during digeftion; and the whole folution at laft grows gelatinous, if the digeftion be performed in an open veffel. If the digeftion be performed in a long-necked or clofe veffel, it does not become gelatinous; but will afterwards become fo, if expofed to the air. In the dry way, when one part of iron filings is diftilled with four of acid of arfenic, the mafs makes a great effervefcence towards the end; and, when it becomes dry, it takes fire upon increafing the heat; arfenic and regulus of arfenic being fublimed, and a black friable refiduum being left at the bottom, which contains but little acid of arfenic. In this procefs it appears that the iron, which is a metal very much difpofed to combuftion or calcination, fuddenly deprives the arfenical acid of its vital air, and reduces it to the ftate of calx and regulus; at the fame time that, according to the ancient hypothefis, phlogifton paffes from the metal to the acid. Little effect is produced upon lead by digeftion with the arfenical acid; but the combination takes place by fufion in the

—on iron:

—on lead.

dry

ARSENIC. Action of arsenical acid on tin:

dry way, which affords a femi-opake glafs. When this is boiled in diftilled water, the lead falls down in the form of a white powder, containing arfenical acid, but which does not afford arfenic by heat, unlefs charcoal be added. Tin, digefted with arfenical acid, grows black at firft; afterwards becomes covered with a white powder; and, at laft, the whole mafs becomes gelatinous. In the dry way, one part of tin filings, with two of the acid, heated in a retort, took fire when ignited: and the calx of regulus of arfenic immediately fublimed, leaving a limpid folution of tin; which, when cooled, was of a milky colour. This, when diffolved in diftilled water, depofited a white calx, which contained very little acid of arfenic.

—on zinc.

Zinc is the only metallic fubftance which effervefces when digefted with the arfenical acid. The zinc grows black; and the tranfparency of the acid is deftroyed by a quantity of black powder; which, on examination by burning on a red-hot iron, proves to be regulus of arfenic. This precipitated regulus foon defends the zinc from farther folution. The air which efcapes during the effervefcence is inflammable, holding regulus of arfenic in folution, which it depofits on burning. Either of the chemical theories will ferve to explain thefe effects: for the zinc is calcined by receiving the vital air of the acid; while it is fuppofed to give out phlogifton enough to reduce the acid bafis to a regulus, and to afford the inflammable air which efcapes. Or, in the other theory, it will be faid that the zinc, having a ftrong tendency to combine with vital air, and become calcined, cannot decompofe water

ARSENIC.

Action of arsenical acid on zinc.

Theory.

at a moderate temperature, unless an acid be present, to remove the coating of calx by solution as fast as it is formed, which mere water cannot do. This therefore is the first consequence of the mutual action of water, zinc, and the acid; namely, vital air quits the water to unite with the zinc, and inflammable air flies off at the same time that the acid combines with the calx of zinc. But of the two metallic bases, which are here combined by the intermedium of vital air, the zinc has a strong tendency to calcination, and the arsenic to become revived: it appears therefore, from the facts, that the zinc, attracting the vital air most strongly, becomes still more calcined, and consequently less soluble; while the arsenic is reduced by the loss of its vital air. Whence it must follow, that the metallic zinc which remains, being enveloped with calx of zinc and metallic arsenic, can no longer be acted on by the acid and water, which still continue undecomposed. On this, and similar occasions, it cannot however be too often repeated to the chemical student, that theories ought to be cautiously followed, as of use in the arrangement of facts, and in directing the path to future investigations; that discriminating phenomena ought to be earnestly sought after, because of infinitely more value than the most ingenious speculations; and that an attachment to system, though it frequently gives life and energy to the exertions of genius, is in general a certain source of prejudices, which disable the enquirer from pursuing the search after truth, and fix his mind upon words instead of things.

Caution respecting theories.

In

ARSENIC.

Action of arsenical acid on zinc:

In the dry way, when one part of the filings of zinc was mixed with two of the arſenical acid, and diſtilled, the maſs took ſire, with a very bright inflammation, as ſoon as the retort became red-hot. The veſſel was burſt by the exploſion; and in its neck were found regulus of arſenic, and flowers of zinc. This effect may be explained from the ſame conſiderations as were applied to the combuſtion which takes place, in like circumſtances, with iron.

—on biſmuth:

Biſmuth is acted upon by the arſenical acid in digeſtion. Water precipitates a powder from the ſolution, which conſiſts of acid of arſenic, combined with calx of biſmuth. In the dry way, biſmuth is calcined by this acid, but not diſſolved; a little arſenic being ſublimed: and if water be added to the cooled maſs, the acid is taken up, but the calx remains. Regulus of antimony is affected nearly in the ſame manner as biſmuth, in the humid way; but, in the dry way, an inflammation takes place at the time of fuſion. By digeſtion with cobalt, the acid of arſenic aſſumed a roſe colour; but much of the cobalt remained undiſſolved. The whole maſs being diſtilled to dryneſs, and fuſed, afforded glaſs of a violet colour, and ſemitranſparent. Nickel communicates a green colour to this acid by digeſtion; a quantity of green powder, mixed with arſenic, being precipitated: the arſenic may be ſeparated by a gentle heat. In the dry way, the acid combines with nickel, and forms a yellow maſs, with grey ſtreaks upon it, reſembling a vegetation. By boiling in water, the acid is taken up, and a yellow powder left behind, conſiſting of a combination of

—on antimony —on cobalt: —on nickel.

ARSENIC.

nickel and arsenic, most probably in the acid state: the arsenic is reduced with charcoal, but the nickel is not. Calx of manganese is scarcely acted upon by acid of arsenic; but, when the manganese is partly or entirely reduced, it is dissolved in the humid way; and affords crystals as soon as the acid is nearly saturated. The regulus, digested with the arsenical acid, becomes covered with a white powder of arsenical calx. When one part of the regulus was mixed with two parts of the dry acid, and exposed to distillation, the regulus was sublimed before the heat was sufficiently great to fuse the acid, and consequently no mutual action took place; but when the acid was first fused, and the regulus added successively in small lumps, inflammation took place, and calx of arsenic was sublimed.

Action of arsenical acid on manganese.

Combinations of regulus of arsenic.

Regulus of arsenic is soluble in unctuous oils, in a boiling heat: the solution is black, and has the consistence of salve when cold *. Most metals unite with arsenic; which most probably exists, in the reguline state, in such as possess the metallic brilliancy. The calx, more or less acidified, is common in many minerals.

Uses of arsenic.

Arsenic is used in a variety of arts. It enters into metallic combinations wherein a white colour is required. Glass manufacturers use it; but its effect in the composition of glass does not seem to be clearly

* On arsenic and its acid, consult Scheele's Essays, p. 143; Bergman's Essays, vol. ii.; Pelletier, in the Journal de Physique for 1782, &c. &c.

explained.

ARSENIC.

explained. Orpiment and realgar are ufed as pigments. Some attempts have been made to introduce it into medicine; but as it is known to be a moft violent poifon, it is probable that the fear of its bad effects may long deprive fociety of the advantages it might afford in this way.

CHAP. XII.

CONCERNING COBALT.

COBALT.

Characters of cobalt.

COBALT is a femi-metal, of a whitifh grey, or fteel colour; hard, brittle; of a dull, clofe-grained fracture, and moderate fpecific gravity. It is rather more difficult of fufion than copper; does not eafily become calcined; and its calx is of fo deep a blue colour, as to appear black. The moft remarkable and moft valuable property of this metallic fubftance is, that its calx, when fufed with borax, or with alkali and fand, produces a blue glafs, known by the name of fmâlt. The action of air foon tarnifhes it; but water has little or no effect upon it.

Combination with vitriolic acid:

Concentrated and boiling vitriolic acid, diftilled nearly to drynefs, combines with this femi-metal. Much vitriolic acid air flies off; and the cobalt is in part calcined; and in part converted into a cryftallizable falt, foluble in water, and precipitable by lime and by alkalis in the form of a rofe-coloured powder or calx. Diluted vitriolic acid acts upon the calx of cobalt, and forms the fame falt.

—with nitrous acid.

Nitrous acid diffolves cobalt by the affiftance of a moderate heat. Nitrous air is difengaged; and the folution affords deliquefcent cryftals by evaporation, which do not detonate on ignited coals, but boil up and leave a red calx. Lime, and the alkalis, precipitate the folution; and, if the alkali be added in excefs, it diffolves the precipitate.

The

The marine acid has ſcarcely any action on cobalt, unleſs it be boiling; in which caſe it diſſolves a ſmall portion. It diſſolves the calx more readily; with which it forms a red brown fluid, that becomes green when heated. This ſolution affords deliqueſcent cryſtals by evaporation.

Combination with marine acid:

Aqua regia diſſolves cobalt more eaſily than the marine, though not ſo readily as the nitrous, acid. This ſolution is well known, as one of the moſt celebrated ſympathetic inks afforded by chemiſtry. If it be diluted with a ſufficient quantity of water to prevent its action upon paper, and then uſed to write with, the letters are inviſible as ſoon as the clear ſolution has become dry: but, if the paper be held to the fire for a ſhort time, they appear of a fine green colour; which again diſappears by removing it, and ſuffering it to cool again. If the heat be continued too long after the letters appear, it will render them permanent. This effect ſeems to be analogous to that which obtains in the marine ſolution: but none of the efficient cauſes of change of colour in this, or any other chemical phenomenon, have been hitherto explained.

—with aqua regia.

Sympathetic ink.

The acid of borax does not act immediately on cobalt, in the humid way: but borax itſelf, added to either of the foregoing ſolutions, effects a decompoſition by double affinity; the alkali uniting with the ſolvent acid, while the acid of borax ſeizes the cobalt, and forms a ſcarcely ſoluble compound, which falls down.

Acid of borax and cobalt.

The acid of ſugar precipitates cobalt from its ſolutions, in the form of a pale roſe-coloured powder.

Acid of ſugar.

Whether

COBALT.

Habitudes of cobalt :

Whether alkalis or earths combine with this metal directly, by the intervention of water, has not been determined.

—with nitre :

Cobalt does not act on neutral salts in general. It detonates feebly with nitre, when projected into a red-hot crucible, with twice or thrice its weight of that salt. The metal becomes calcined by the action of the nitre; but the changes in both substances require farther examination.

—with sal ammoniac :

Sal ammoniac is not decomposed by cobalt.

—with sulphur :

Sulphur does not unite with cobalt, but with difficulty. Liver of sulphur combines more readily with it. The action of phosphorus, or its acid, on this substance, remains to be ascertained.

—with metallic substances.

This semi-metal unites by fusion with most of the metals and semi-metals, as has before been noticed. Silver, lead, and bismuth, do not mix with it; and zinc does not but with great difficulty.

Native cobalt and its ores.

Cobalt is found native in alloy with arsenic and iron, and of a steel-grained appearance when broken; or in a calciform state, of a black colour, either pulverulent or indurated: or combined with arsenical acid, in the flowers of cobalt, of a red colour; or, lastly, united to sulphur and iron, with or without arsenic, of various shades of redness. Bismuth, nickel, and other substances, are contained in these ores. They may in general be distinguished by solution in aqua regia; with which, after dilution with water, they form the sympathetic ink above described.

Humid analysis.

The native cobalt, and its calciform or sulphureous ores, may be examined by solution in aqua regia, and evaporation to dryness; after which, the calcined

calcined cobalt may be diffolved by vinegar. When this calx is precipitated by mild mineral alkali, the regulus may be accounted for, by allowing one hundred grains for every hundred and fixty grains of precipitate. The other component parts of the refidue, not taken up by the vinegar, may be afcertained by the methods defcribed in the preceding chapters. The red arfenical cobalt ore, which contains arfenical acid, may be decompofed by vitriolic acid; and the difengaged arfenical acid will be taken up by highly-rectified fpirit of wine; after which, the combination of vitriolic acid and cobalt may be diffolved in water, and precipitated by mild alkali: or the ore itfelf may be diffolved in water, fharpened by an acid; and the calx be then precipitated by the alkali.

Humid analyfis of cobalt ores.

In the dry way, the ores of cobalt, after previous pounding, wafhing, and roafting, may be fufed with three times their weight of black flux, in a lined and covered crucible, by the heat of a fmith's forge. The tingeing power of cobalt ores may be affayed by fufion with three parts of fixed alkali, and five of powdered flint, or glafs. The alkali muft be put firft into the crucible; next, the flint; and, above all, the roafted ore. When cobalt ores, containing bifmuth, are reduced, this femi-metal ufually occupies the lower part of the crucible, and may be feparated from it by a blow with a hammer; or at leaft by eliquation, or melting, on account of its greater fufibility.

Analyfis in the dry way.

Cobalt is found in feveral parts of Europe, but moft plentifully in Saxony; or, at leaft, it is manufactured there in the greateft plenty. Chaptal affures

Cobalt found moft plentifully in Saxony.

COBALT.

Manufacture of zaffre and ſmalt.

us, that the Saxons at preſent import it from the ſouth of France, where it is afforded by the Pyrenean mountains. The ore is uſually broken into pieces about the ſize of a hen's egg, and the ſtony parts picked out. The ſorted mineral is then pounded in mills, and ſifted through wire ſieves. By waſhing in water, the lighter parts are carried off; and the remainder is calcined in a furnace reſembling an oven, wherein it is heated by the action of the reverberated flame of wood which plays upon it. In this ſituation, it is occaſionally ſtirred with long iron rakes; and emits fumes, conſiſting chiefly of arſenic, which is collected in a long horizontal chimney, built for that purpoſe. If the ore contain biſmuth, this fuſible ſemi-metal is collected at the bottom of the furnace. The cobalt, after a ſufficient torrefaction, remains in the form of a dark grey calx, called zaffre. The zaffre of commerce always contains twice or thrice its weight of powdered flints. The flint is pulverized, for this and other purpoſes, by means of previous ignition, and quenching in water, which renders it friable. Smalt is a blue glaſs, compoſed of one part of the calcined cobalt, fuſed with two of the flint powder, and one of pot-aſh. Powder blue, or azure, is obtained by grinding ſmalt in mills, and afterwards waſhing it in water. This laſt operation is performed in a caſk filled with water, and pierced with three openings at different heights. The water of the uppermoſt cock carries out the fineſt blue, which they call azure of the firſt fire. The larger particles fall more ſpeedily, and the azure brought out by the water of the three cocks forms the different degrees of fineneſs known under

under the names of azure of the firſt, ſecond, and third fires. COBALT.

The uſe of this metallic ſubſtance is confined chiefly to the production of the blue glaſs for enamels, and other purpoſes. Powder and ſtone blue, uſed by laundreſſes, is a preparation made by the Dutch from the coarſe ſmalt. Uſes of cobalt.

CHAP.

CHAP. XIII.

CONCERNING ZINC.

ZINC. Characters of zinc.

ZINC is a femi-metal, of a blueifh white colour, fomewhat brighter than lead; of confiderable hardnefs; and fo malleable, as not to be broken with the hammer, though it cannot be much extended in this way. It is very eafily extended by the rollers of the flatting mill. When broken by bending, its texture appears as if compofed of cubical grains. On account of its imperfect malleability, it is difficult to reduce it into fmall parts by filing or hammering: but it may be granulated, like the malleable metals, by pouring it, when fufed, into cold water; or, if it be heated nearly to melting, it is then fufficiently brittle to be pulverized. It melts long before ignition, at about the 700th degree of Fahrenheit's thermometer; and, foon after it becomes red-hot, it burns with a dazzling white flame, of a blueifh or yellowifh tinge, and is calcined with fuch rapidity, that it flies up in the form of white flowers, called the flowers of zinc, or philofophical wool. Thefe are generated fo plentifully, that the accefs of air is foon intercepted; and the combuftion ceafes, unlefs the matter be ftirred, and a confiderable heat kept up. The white calx of zinc is not fo volatile, but is driven up merely by the force of the combuftion. When it is again urged by a ftrong heat, it becomes converted into a clear yellow glafs.

glafs. If zinc be heated in clofed veffels, it rifes without decompofition. Zinc appears to be the moft volatile of metallic fubftances, except the regulus of arfenic.

The diluted vitriolic acid affords zinc; at the fame time that the temperature of the folvent is increafed, and much inflammable air efcapes: an undiffolved refidue is left, which confifts of plumbago. The theories of this folution, and the difengagement of inflammable air, are perfectly fimilar to thofe which have been before explained in the chapter on iron. As the combination of the vitriolic acid and the calx proceeds, the temperature diminifhes; and the vitriol of zinc, which is more foluble in hot than cold water, begins to feparate, and difturb the tranfparence of the fluid. If more water be added, the falt may be obtained in fine prifmatic four-fided cryftals. The white vitriol, or copperas, ufually fold, is cryftallized haftily, in the fame manner as loaf fugar, which, on that account, it refembles in appearance: it is flightly efflorefcent. The white calx of zinc is foluble in the vitriolic acid, and forms the fame falt as is afforded by zinc itfelf.

Solution of zinc in vitriolic acid.

White vitriol.

Diluted nitrous acid combines rapidly with zinc, and produces much heat, at the fame time that a large quantity of nitrous air flies off. The folution is very cauftic, and affords cryftals by evaporation and cooling, which flightly detonate upon hot coals, and leave a calx behind. This falt is deliquefcent.

Solution of zinc in nitrous acid:

Marine acid acts very ftrongly upon zinc, and difengages much inflammable air; the folution, when evaporated, does not afford cryftals.

—in marine acid.

Water

ZINC.

Water impregnated with fixed air diſſolves a conſiderable proportion of zinc. The other acids have not been tried.

Habitudes of zinc:

Zinc is precipitated from acids, by the ſoluble earths, and the alkalis: the latter rediſſolve the precipitate, if they be added in exceſs.

—with vitriolic ſalts:

Zinc decompoſes, or alters, the vitriolic neutral ſalts in the dry way. When fuſed with vitriolated tartar, it converts that ſalt into liver of ſulphur; the zinc at the ſame time being calcined, and partly diſſolved in the hepar. In this operation, the vital air of the acid combines with the zinc, and calcines it; at the ſame time that, according to the ancient theory, the phlogiſton of the metal combines with the acid baſe, and converts it into ſulphur. In the new theory, the tranſition of phlogiſton is conſidered as hypothetical and unneceſſary: becauſe, the metal and the ſulphur being taken to be ſimple ſubſtances, the vitriolic acid becomes ſulphur, merely by the loſs of its vital air; and the zinc becomes calcined merely by the acquiſition of the ſame ſubſtance.

—with nitre:

When pulveriſed zinc is added to fuſed nitre, or projected together with that ſalt into a red-hot crucible, a very violent detonation takes place; inſomuch that it is neceſſary for the operator to be careful in uſing only ſmall quantities, leſt the burning matter ſhould be thrown about. The zinc is calcined; and part of the calx combines with the alkali, with which it forms a compound, ſoluble in water.

—with common ſalt; ſal ammoniac; and alum.

Zinc decompoſes common ſalt, and alſo ſal ammoniac, by combining with the marine acid. The filings of zinc likewiſe decompoſe alum, when boiled in a ſolution

ſolution of that ſalt, probably by combining with its exceſs of acid.

ZINC.

Habitudes of zinc with ſulphur:

Sulphur, though its action is almoſt general on metallic ſubſtances, does not combine with zinc. This property affords a ready means of purifying the ſemi-metal, by projecting ſulphur upon it, when melted in a ſhallow crucible. It has been a ſubject of remark, among chemiſts, that many of the zinc ores conſiſt of this ſemi-metal combined with ſulphur, though art has not yet diſcovered the means of effecting the ſame combination. But the difficulty is removed by the conſideration, that the ſulphur does not unite with zinc itſelf; yet it readily does with its calx, and forms a compound ſimilar to the zinc ores, called blendes; in which, for that reaſon, the zinc may be preſumed to exiſt in the calciform ſtate.

—with liver of ſulphur:

Liver of ſulphur does not combine with zinc, either in the humid or dry way.

—with metals.

Moſt of the metallic combinations of zinc have been already treated of. It forms a brittle compound with antimony; and its effects on manganeſe, wolfram, and molybdena have not yet been aſcertained.

Native zinc and its ores.

Native zinc has been very ſeldom found. The calciform ores of zinc are the zinc ſpar, of a whitiſh grey colour, reſembling a lead ſpar; and the impure calx called calamine, which is of a white, grey, yellow, brown, or red colour, containing iron, clay, calcareous and other earths, and lead. The ore called blende, mock lead, or black jack, conſiſts of zinc mineralized with ſulphur and iron: of this there are ſeveral varieties. They are in general of a plated texture; and frequently of a quadrangular

 form,

ZINC.

form, like galena, or potters' lead ore, though they are considerably leſs heavy. Theſe ores are found in various parts of Europe; and, in conſiderable plenty, in the mine counties of England.

Humid analyſis of zinc and its ores.

Native zinc may be aſſayed, in the humid way, by the mineral acids. When it is diſſolved in theſe, if there be any other metal preſent, it may be precipitated by the addition of a known quantity of zinc. The weight of calx of zinc precipitated by mild alkali from its vitriolic ſolution, will amount to 193 grains for every 100 of the metal it repreſents. The ſulphureous zinc ores muſt be carefully treated with nitrous acid; which will diſſolve the zinc, and leave the ſulphur. Extraneous metals may be precipitated, and the quantity of zinc aſcertained, as before.

Eſſay of calamines.

The eſſay of calamines is ſometimes made by pounding and mixing them with charcoal, and then heating them in a crucible covered with a copper plate. The reduced zinc riſes, and converts the copper into braſs; and, in this way, ſome judgment may be formed of its value in the operation of braſs-making. Moſt of the zinc, whether in the metallic ſtate, or in the form of an impure calx, called cadmia fornacum, is obtained in the roaſting of various kinds of ores at Ramelſburg. For this purpoſe, the anterior part of the furnace is kept cold by wetting it: by which means the volatilized zinc is condenſed, and falls into a cavity, containing charcoal duſt, which defends it from calcination.

Diſtillation of zinc.

The proceſs for obtaining zinc from its ores by diſtillation, which is practiſed in England, and ſaid to have originally been derived from the Chineſe, is per-

 formed

ZINC.

formed in a furnace, in the form of a circular oven; in which are placed fix pots, each about four feet in height, and of a conical fhape, refembling an oil jar. Into the bottom of each pot an iron tube is inferted, which paffes through the floor of the furnace into a veffel of water. Thefe pots are filled with a mixture of calamine and charcoal; and their mouths are then clofe ftopped with clay. The fire being then properly applied, the metallic vapour of the calamine iffues through the iron tube, which is the only place where it can efcape. In this way it is condenfed in fmall particles in the water; which are afterwards melted into ingots for fale, under the name of fpelter*. The fubftance fold in London by the name of fpelter, is a kind of foft brafs, in a granulated form, which is ufed by the braziers and others for foldering.

Diftillation of zinc.

Spelter.

The chief purpofe to which zinc is applied confifts in the fabrication of brafs, and other gold-coloured mixtures. Its calces and falts have been occafionally employed in medicine.

Ufe of zinc.

* Watfon's Chemical Effays, vol. iv.

CHAP. XIV.

CONCERNING ANTIMONY.

ANTIMONY. Characters of antimony.

REGULUS of antimony is of a ſilvery white colour; very brittle, and of a plated or ſcaly texture. Its ſpecific gravity is moderate. Soon after ignition it melts; and, by a continuance of the heat, it becomes calcined, and riſes in white fumes, which may afterwards be volatilized a ſecond time, or fuſed into a hyacinthine glaſs, according to the management of the heat: they are called argentine flowers of regulus of antimony. In cloſed veſſels, the regulus riſes totally without decompoſition. This metallic ſubſtance is not ſubject to ruſt by expoſure to air; though its ſurface becomes tarniſhed by that means. Its calces are ſoluble in water; and, in that reſpect, reſemble the calx of arſenic, probably by an approach towards the acid ſtate.

Action of vitriolic acid on antimony.

Vitriolic acid, boiled upon the regulus of antimony, calcines the greater part, ſo as to render it inſoluble; the acid being at the ſame time decompoſed. Much vitriolic acid air eſcapes; and, towards the end, a ſmall quantity of ſulphur is ſublimed. By waſhing the reſidue in water, a vitriolic ſalt of antimony is ſeparated from the calx, which does not cryſtallize.

Nitrous acid.

Nitrous acid very readily attacks antimony in the cold. Moſt part of the metal is calcined by this action; but a portion is diſſolved, and affords deliqueſcent cryſtals, decompoſible by heat. The calx of antimony

antimony formed by this acid is very white, and difficult of reduction. ANTIMONY.

Solution of antimony in marine acid:

Continued digeftion is required for the folution of regulus of antimony in the marine acid. A confiderable quantity is however at length diffolved; which affords very deliquefcent cryftals. This falt melts by the application of heat; and is decompofed by diftilled water, in the fame manner as the butter of antimony, from which it does not much differ.

—in dephlogifticated or aërated marine acid:

Dephlogifticated or aërated marine acid diffolves the regulus of antimony with great facility.

—in aqua regia.

Aqua regia, compofed of feven parts nitrous, and one marine acid, diffolves it very readily; but lets fall a portion of white calx as it cools. The folvent power of either of the three ancient mineral acids on this femimetal, appears to be increafed by mixture with any one of the others.

Habitude of regulus of antimony with earths:

Earthy fubftances do not act on the regulus of antimony in the dry way. Its calx, however, enters readily into the compofition of glafs; to which it imparts more or lefs of an hyacinthine colour. When fufed with vitriolated tartar, it converts it partly into hepar, or liver of fulphur; which diffolves a portion of the calx of antimony: that is to fay, the vital air of the acid calcines the regulus of antimony, while part of the acid becomes converted into fulphur; either fimply by the lofs of its vital air, or elfe by that lofs, together with the acquifition of phlogifton from the regulus.

—with vitriolated tartar.

Detonatio with nit

Nitre detonates very readily with the regulus of antimony: when equal parts of thefe fubftances are projected into a red-hot crucible, the refidue of calx and alkali is known by the name of diaphoretic antimony.

ANTIMONY. mony. When the faline part is wafhed out by hot water, the refidue is called wafhed diaphoretic antimony. The water ufed in the wafhing contains a portion of the calx, fufpended by the alkali. This may be precipitated by the addition of an acid, and has been diftinguifhed by the name of cerufe of antimony.

Diftillation of regulus of antimony with corrofive fublimate.

When regulus of antimony is pulverized, and accurately mixed with about twice its weight of corrofive fublimate, a mutual action takes place with the production of heat; and, if the mixture be diftilled with a gentle fire, a thick fluid comes over, which congeals in the receiver, or in the neck of the retort, and is called butter of antimony. The refidue confifts of revived mercury, and fome regulus and calx of antimony. In this experiment, the dephlogifticated marine acid combines with the antimony, while the mercury is revived; as may be eafily explained on either of the two theories of chemiftry. If the combination of regulus of antimony and fulphur be ufed inftead of the regulus itfelf, the mercury will be obtained in the form of cinnabar, at a much greater heat than is required to fublime the butter of antimony.

Butter of antimony.

Theory.

Powder of algaroth.

When butter of antimony is thrown into pure water, an abundant white precipitate, or calx, falls down, which is a violent emetic, and is known by the name of powder of algaroth.

Bezoar mineral.

Nitrous acid diffolves the butter of antimony. The folution, which does not appear to differ greatly from the folution of the regulus in aqua regia, foon depofits a portion of calx. When an equal weight of nitrous

nitrous acid has been three times diſtilled to dryneſs from butter of antimony, the reſidue, after ignition, is called bezoar mineral; and ſeems to be little more than a calx of the metal.

Combination of regulus of antimony with ſulphur:

Sulphur combines very readily with the regulus of antimony, and forms a ſubſtance differing in no reſpect from the mineral, or ore, to which the name of antimony is excluſively appropriated. One part of ſulphur completely mineralizes four of the regulus.

—with liver of ſulphur.

Liver of ſulphur diſſolves the regulus of antimony, and affords an orange-coloured precipitate upon the addition of an acid.

Crude antimony:

Antimony, or the regulus combined with ſulphur, was a favourite object of reſearch in the experiments of the alchemiſts; in conſequence of which, its properties are much better known than thoſe of the pure regulus. If this ſubſtance be heated, it melts, and a conſiderable portion of the ſulphur flies off, at the ſame time that the regulus becomes calcined, and riſes in white vapours. A gentler heat, leſs than is neceſſary to fuſe it, converts it into a grey calx: this calx contains a portion of ſulphur. If it be urged by a ſtronger heat, it melts into the form of glaſs, which is more or leſs tranſparent, according to the degree of calcination of the metal, and the diſſipation of the ſulphur. When it contains much ſulphur, the glaſs is fuſible, opake, and of a dark red colour; whence it has been called liver of antimony.

—its habitudes: —by heat:

—with acids.

When acids are applied to crude antimony, they diſſolve the regulus, and leave the ſulphur. The nitrous acid is beſt adapted to this ſolution.

 Dia-

ANTIMONY.

Diaphoretic antimony.

Diaphoretic antimony is moſt commonly and advantageouſly prepared by detonating the crude antimony with nitre inſtead of the regulus; the only difference being, that more nitre is required for the detonation; and that the reſidue contains vitriolated tartar, as well as alkali and calx.

Antimonial medicines.

There are ſeveral preparations, conſiſting of combinations of antimony with an alkali, in which the proportions of the ingredients, and the ſtate of the calx, are very different, according to the nature and management of the proceſſes. Many of theſe have been highly praiſed in medicine; at the ſame time that they have been as ſtrongly exclaimed againſt for their ill effects. Both theſe aſſertions appear to have been well founded. It is ſufficiently proved that antimonial medicines have produced the happieſt effects, and are juſtly entitled to be conſidered as very powerful remedies; but, on the other hand, it is equally certain, that their great efficacy muſt have required greater attention, in their firſt exhibition, than perhaps may have been paid; and the complicated nature of many of the proceſſes muſt have rendered it very difficult to produce ſubſtances poſſeſſing exactly the ſame properties, or proportion of component parts, at all times.

Kermes mineral.

If antimony be treated with a fixed alkali, either by fuſion and ſubſequent ſolution in boiling water, or by ſimple ebullition, a precipitate is afforded by cooling, which is called kermes mineral, formerly uſed in medicine. It is thought to conſiſt of the calx of antimony, in combination with a portion of ſulphur; but its com-

component parts have not been accurately determined, and its properties differ according to the various methods used in preparing it. ANTIMONY.

Antimonial medicines.

The antimonial preparations most commonly used at present are, antimonial wine, and emetic tartar. These, like every other preparation of this semi-metal, are prepared in a variety of ways. The wine may be had by infusing pulverized glass of antimony in Spanish white wine for some days, and then filtering the clear fluid through paper. A very minute portion of the calx is taken up; and this is greater or less, according as the wine is more or less acid; and, perhaps, according to the temperature of the weather at the time of administering it. On this account, it is found necessary to give this medicine cautiously, and by small portions at a time, when it is intended that it shall act as an emetic.

Emetic wine.

Antimoniated tartar.

The emetic or antimoniated tartar of the London College is thus prepared:—Take of crude antimony and nitre equal parts, separately reduced to powder; mix them, and inject them into a crucible heated to whiteness, that the mixture may melt after deflagration; pour it out, and reserve the yellow mass beneath the scoriæ, under the name of crocus of antimony; reduce this to a very subtile powder; boil it in water, and wash the powder repeatedly in warm water, till it becomes perfectly insipid: then take equal parts, by weight, of the washed crocus of antimony and of crystals of tartar, and boil them together, in three pints of water for every pound of the mixture, during half an hour: filter the liquor; and, after due evaporation, set it by to crystallize.—This is the antimoniated

 tartar.

tartar. It is a triple falt, confifting of the acid of tartar, united to vegetable alkali, and antimony partially calcined; and is confidered as a fafe medicine, whofe properties and effects are more conftant, and milder, than moft other antimonial remedies.

Medical effects of antimony.

It has not been clearly determined on what circumftances the medical effects of antimony depend. The faline preparations of mercury, and other metals, are fuppofed to derive their caufticity from their tendency to become reduced to the metallic ftate; in confequence of which, they corrode and decompofe other combuftible fubftances: but whether this be the cafe with antimony, is doubtful. It appears neceffary, however, that antimony fhould be in the faline ftate, in order that it may act upon the animal fyftem. When the regulus is made into thofe fmall balls or pills, which, on account of the little change they undergo in paffing through the human body, have been called perpetual pills, its purgative action is more or lefs violent, according to the quantity of acid it meets with; and, in the preparations of this femi-metal, their effects feem likewife to be governed by the fame circumftance joined to their refpective degrees of folubility. The nearly pure and infoluble calx, produced by detonation with a large proportion of nitre, is almoft ineffectual; whereas the more foluble calces or combinations are more or lefs active, according to their refpective nature. Hence it appears to follow, that the fimpleft faline combinations are the moft likely to produce effects conftantly fimilar; and that moft of the calces and combinations, fo highly extolled in the earlier age of chemiftry, are attended with dangerous uncertainty in their operation.

Perpetual pills.

Antimony

Antimony combines with moſt other metallic ſubſtances, and produces mixtures whoſe properties have been attended to under their reſpective titles.

Native antimony and its regulus.

Antimony is found either native, in maſſes of the regulus, compoſed of ſhining irregular plates; or calciform, in white cryſtallized filaments; or combined with ſulphur, in the dark blueiſh or grey friable mineral, called antimony, conſiſting moſt commonly of brilliant filaments diſpoſed parallel to each other; or, laſtly, combined with ſulphur and arſenic, in an ore which greatly reſembles the foregoing, except that it is of a red or reddiſh colour.

Humid analyſis.

Native regulus of antimony, or its calx, may be aſſayed by nitrous acid, which diſſolves whatever arſenic it may contain, and only calcines the antimony. The ſulphureous antimonial ores are moſt conveniently analyſed by aqua regia, which takes up the calx, and leaves the ſulphur, which may be ſeparated by filtration. The remaining ſolvent may be examined with the uſual precipitants.

Dry way.

In the dry way, antimony is ſeparated from its ſtony parts by fuſion in a moderate heat, nearly in the ſame manner as biſmuth; and may be reduced, by ſlowly roaſting it, till it becomes converted into a grey calx, which may be briſkly fuſed with twice its weight of black flux.

Uſes.

Antimony and its regulus are chiefly uſed in medicine, and in ſome metallic alloys, ſuch as that uſed for printers types, ſmall ſhot, &c.

CHAP.

CHAP. XV.

CONCERNING MANGANESE.

MANGANESE. Characters of manganefe.

THE regulus of manganefe is a femi-metal of a dull whitifh colour when broken, but foon grows dark by calcination from the action of the air. It is hard, brittle, though not pulverable, and rough in its fracture; fo difficultly fufible, that no heat yet exhibited has caufed it to run into maffes of any confiderable magnitude; and appears to be more difpofed to calcination than any other metallic fubftance, unlefs we may except wolfram. Its calces are white when imperfect; but black, or dark green, when perfect: the white are foluble in acids. When broken in pieces, it falls into a powder by fpontaneous calcination; and this powder is magnetic, though the maffes were not poffeffed of that property. It feems as if the regulus of manganefe were capable of depriving a fmall proportion of iron of its magnetifm; but that the effect ceafes as foon as that regulus is converted into calx. A ftrong heat expels vital air from the calx of manganefe.

Concentrated vitriolic acid attacks the regulus of manganefe, but much more readily when diluted with two or three times its weight of water; at the fame time that inflammable air is difengaged. A black fpongy fubftance remains undiffolved, which has not been examined. The folution is colourlefs, and affords cryftals cryſtals by evaporation. Mild alkalis precipitate a white calx, ſoluble in acids; but pure alkalis afford a brown calx, which ſoon grows black in the air, and is ſcarcely ſoluble. The black calx of manganeſe, when old, or well made, is altogether inſoluble in acids, unleſs ſome combuſtible ſubſtance be added. It appears therefore that the metal in this ſtate is too far calcined, and requires to be reduced again in a certain degree towards the metallic ſtate, to be diſſolved. If vitriolic acid be added, and drawn off by diſtillation ſeveral times from the black calx, by an heat nearly approaching to ignition, in a glaſs veſſel; it is found that vital air is diſengaged towards the end of each proceſs, and part of the calx is diſſolved. The ſolution of the calx in acids, by the addition of combuſtible matter, is eaſily accounted for, on either of the theories of chemiſtry, by affirming that the reduction is effected by the addition of phlogiſton, or the ſubtraction of vital air from the calx by means of the combuſtible ſubſtance. The phlogiſtic theory appears however to be deficient, in explaining the ſolution by mere vitriolic acid, at an elevated temperature *, on account of the abſence of phlogiſton; but the new theory ſimply aſſerts the facts, that the calx loſes vital air in conſequence of the elevated temperature, and is rendered ſoluble in the acid.

Black calx of manganeſe.

Theory.

* Bergman, ii. 215 (on the hypotheſis, that heat is matter; that this matter conſiſts of pure air united to phlogiſton; and that manganeſe decompoſes the heat), derives the phlogiſton required for the ſolution, as well as the vital air which flies off, from this decompoſition. Theſe poſitions did not appear ſufficiently grounded to enter the text.

Nitrous

MANGANESE.

Solution of regulus of manganese in nitrous acid:

Nitrous acid diffolves the regulus of manganefe with effervefcence, and the efcape of nitrous air. A fpongy, black, and friable matter remains, whofe properties refemble molybdena. The folution does not afford cryftals. The perfect calx is not foluble in pale nitrous acid, unlefs fome combuftible matter be added.

—in marine acid.

The regulus is diffolved in the ufual manner by marine acid. The black calx is likewife foluble; but adheres fo weakly to the acid, as to be feparated even by the mere addition of water: but, if this folution be expofed to a digefting heat for fome hours, an inteftine motion, like an effervefcence, takes place; the fmell of dephlogifticated or aërated acid is perceived; and the combination becomes more perfect, fo as not to afford a precipitate, unlefs an alkali be added. Marine acid diffolves the black calx alfo, by the addition of a combuftible fubftance. Mercury, and even gold, will effect this combination. The folution of manganefe in marine acid fcarcely affords cryftals, but a deliquefcent faline mafs by evaporation, which is foluble in ardent fpirit.

Explanation.

In the permanent folution of black calx of manganefe by marine acid, it is feen that the acid itfelf muft communicate the property to the calx, on which its folubility depends; that is to fay, it muft either afford phlogifton, or abforb vital air: and accordingly, the red vapours which efcape are diftinguifhed by the name of dephlogifticated, or aërated, marine acid, according to the theory which may be adopted by the fpeaker.

Other

Other acids likewife diffolve this metallic fubftance. The fluor acid, and alfo the phofphoric acid, form compounds of difficult folubility, which envelop and defend it from their farther action in a fhort time.

Combinations of calx of manganefe in the dry way.

In the dry way, the calx of manganefe combines with fuch earths and faline fubftances as are capable of undergoing fufion in a ftrong heat. Thefe experiments are moft advantageoufly performed by the blow-pipe, on fmall quantities of matter; becaufe, in this way, the whole of the phenomena are clearly feen. The moft remarkable property of the folutions is, that a due proportion of combuftible matter renders them colourlefs; for which reafon, the calx of manganefe is ufed by the glafs manufacturers to deftroy the colours of glafs. If a globule of microcofmic falt be fufed by the blow-pipe upon charcoal, and a fmall portion of the black calx of manganefe be added, the colour will be of a blueifh red; or of a deep red, if the quantity of calx be greater. If the fufion be continued by the interior blue flame, the colour at length difappears; but may be eafily revived again, by foftening the globule with the exterior flame. A fmall particle of nitre inftantly reftores the red colour; but inflammable matter, or vitriolic falts, contribute to difcharge it. If the globule, after being deprived of all colour, be fufed in the filver fpoon, it recovers its rednefs; and the colour is not difcharged by any management of the fufion, unlefs fome inflammable matter be added.

Changes of colour.

Explanation.

Thefe remarkable changes of colour, which may be repeatedly produced, depend evidently on the prefence or abfence of combuftible matter; or, which amounts

to

MANGANESE.

Explanation of the changes of colour in glaffes which contain manganefe.

to the fame thing, on the degree of calcination of the manganefe which is held in folution. When the highly calcined or black manganefe is firft added, it produces a coloured globule; if inflammable matter be added, the calx is partly reduced, and forms a colourlefs combination. Nitre reftores the colour by its well-known property of calcining metals. When the fufion is performed by the interior flame, the globule may be confidered as if heated in a clofe veffel, in contact with charcoal; becaufe the furrounding flame prevents the accefs of air: a revival of the calx therefore enfues, and the colour vanifhes. But when the external flame is ufed, its apex, or point only, touches the globule; and the furrounding air promotes or maintains the calcination more effectually than the charcoal can produce the contrary effect: the confequence therefore is, that the colour again appears. Vitriolic falts feem to forward the action of the charcoal, which converts them into fulphur; and the colour remains fixed in the fpoon, becaufe there is no combuftible fubftance prefent, which is fufficiently fo to promote the revival of the calx. It is evident that both the theories of chemiftry are applicable to thefe facts, whether the charcoal revives the calx by phlogifticating it, or by depriving it of its vital air; or whether the calcination by the apex of the flame be effected by the diffipation of phlogifton, or by the abforption of vital air from the atmofphere.

Theories.

Nearly fimilar changes are produced when the calx is fufed with borax, or an alkali.

Combination with fulphur.

Regulus of manganefe does not appear to combine with fulphur; but eight parts of the calx combine with

with three of ſulphur, and produce a yellowiſh green maſs, which is acted upon by acids; the metal being diſſolved with effervefcence, and the diſengagement of hepatic air. The remaining ſulphur may be collected on a filter. MANGANESE.

Metallic combinations of manganeſe.

This ſemi-metal melts readily with moſt of the other metals, but rejects mercury. Gold and iron are rendered more fuſible by a due addition of manganeſe; and the latter metal is rendered more ductile. Copper becomes leſs fuſible, and is rendered whiter, but of a colour ſubject to tarniſh *.

Native manganeſe and its ores.

Regulus of manganeſe has been found native among the powdery or calciform ore of this metallic ſubſtance. Its properties, in this ſtate, perfectly reſemble the regulus produced by art. Manganeſe appears to exiſt in the calcined ſtate in all its ores; though contaminated with admixtures of earths, or other metallic matters. They are, white, red, brown, or black; either pulverulent, indurated, or cryſtallized. Vegetable aſhes likewiſe afford indications of manganeſe.

Humid analyſis.

To analyſe the ores of manganeſe in the humid way, they muſt be reduced to a ſubtile powder, and immerſed in a mineral acid, with a piece of ſugar to aſſiſt the ſolution. If nitrous acid be repeatedly abſtracted to ignition from the ore, the iron it contains will be rendered nearly inſoluble from calcination; and the manganeſe may be taken up by ſtrong concentrated vinegar, or diluted nitrous acid. This, when precipitated by mild mineral alkali, affords 180

* Annales de Chimie, i. 303

MANGANESE. grains of precipitate for every 100 grains of regulus: or if the metals be precipitated from ſuperabundant nitrous acid, by Pruſſian alkali, the manganeſe will be totally diſſolved by pure water, while the iron remains behind.

Spontaneous inflammation of black wadd.

The ore of manganeſe, which is known in Derbyſhire by the name of black wadd, is remarkable for its ſpontaneous inflammation with oil. It is of a dark brown colour, of a friable earthy appearance, partly in powder, and partly in lumps. If half a pound of this be dried before a fire, and afterwards ſuffered to cool for about an hour; and it be then looſely mixed or kneaded with two ounces of linſeed oil; the whole, in ſomething more than half an hour, becomes gradually hot, and at length burſts into flame. This effect wants explanation. It ſeems, in ſome meaſure, to reſemble the inflammation of oils by the nitrous acid.

Reduction of manganeſe.

The preſence of manganeſe may be aſcertained in the dry way, by the blow-pipe, from the ſingular changes of colour already deſcribed, when fuſed with microcoſmic ſalt, or borax. The reduction of the ore is effected by mixing it with pitch, making it into a ball, and putting it into a crucible lined with powdered charcoal, one tenth of an inch thick at the ſides, and one quarter of an inch thick at the bottom; then filling the empty ſpaces with powdered charcoal, and luting on a cover. This muſt be expoſed to the ſtrongeſt heat of a forge, or furnace, for an hour, or more. As the calx of manganeſe is ſtrongly diſpoſed to vitrification, fluxes rather impede than forward the reduction. The reduced globules of manganeſe

ganese are usually enveloped with a vitrified crust, which either partly or completely defends them from the action of the air; but, when they are broken, they lose their metallic brilliancy and consistence in a very short space of time.

MANGANESE.

Speedy calcination.

Manganese has hitherto been used chiefly by glass-makers and potters; but the important discoveries of the uses of dephlogisticated or aërated marine acid will, no doubt, extend its utility to several other manufactories *.

Uses of manganese.

* On manganese, consult Scheele, 67—142; Bergman, ii. 201—225; the Memoirs of Pelletier, Berthollet, &c.; and the Abstracts by Elementary Writers on Mineralogy.

CHAP. XVI.

CONCERNING WOLFRAM.

WOLFRAM.

TUNGSTEN and wolfram have already been treated of in the fection on acids; and the combinations of metals with the regulus of wolfram have been occafionally mentioned under their refpective heads. Little elfe remains therefore to be faid of this metallic fubftance, than to fpecify its general characters.

Characters and habitudes of the calx and regulus of wolfram.

The yellow matter, or calx of wolfram, turns blue by expofure to light; and more intenfely, if to the light of the fun. By a ftrong heat in a covered crucible, it becomes of a blueifh black colour, with lofs of weight; which it recovers, together with its original yellow colour, by calcination with accefs of air. Thefe changes to the blue colour appear therefore to be partial reductions *. One hundred grains of the yellow calx, or acid, being put into a crucible with charcoal powder, well covered, and expofed to a ftrong heat, became converted into a button of a dark brown colour, and friable, with a diminution of forty grains of the original weight. Its fpecific gravity was 17.6; and, upon examination with a glafs, a congeries of metallic globules was feen, fome of them of the fize of a pin's head; which, when broke, exhibited a fracture refembling fteel. Part of this mafs

* De Luyarts on Wolfram, page 58.

being

WOLFRAM. Habitudes:

being calcined, became yellow as at firft, and gained twenty-four per cent. in weight. It was not foluble in vitriolic or marine acid; but the nitrous acid, and aqua regia, converted it again into the yellow calx. The yellow calx itfelf could not be vitrified. Acetous acid converted the yellow colour to a blue.

—with fulphur.

When equal parts of fulphur and the yellow calx were urged by a ftrong heat, a blue friable mafs remained, weighing lefs than one-fourth of the whole.

CHAP. XVII.

CONCERNING MOLYBDENA.

MOLYBDENA. Characters of regulus of molybdena.

MOLYBDENA, like manganefe and wolfram, has not been reduced into maffes of any confiderable magnitude; but has been obtained only in fmall feparate globules, in a blackifh brilliant mafs. It has been revived by a procefs fimilar to that by which regulus of manganefe is obtained; but it requires a moft extreme degree of heat for that purpofe. The globules are grey, brittle, and extremely infufible. By heat it is converted into a white calx, which rifes in brilliant needle-formed flowers, like thofe of antimony. Nitrous acid readily calcines and acidifies the regulus. Nitre detonates with it, and the remaining alkali combines with its calx.

Habitudes with various fubftances. See alfo p. 221.

Detonation with nitre decompofes the native molybdena; but folution in nitrous acid is the readieft way to procure the acid of this fubftance. Pruffian alkali, and alfo infufion of galls, precipitate the acid from its folutions. When acid of arfenic is heated with molybdena, it converts part of the fulphur into volatile vitriolic acid; which comes over, and combines with another portion, with which it rifes in the form of orpiment. No other acids but the nitrous and arfenical have any action on crude molybdena.

The

The regulus of molybdena unites with ſeveral of the metals, and forms brittle or friable compounds. MOLYBDENA.

This mineral is ſcarce. It is diſtinguiſhable from black lead by its more ſhining ſcaly appearance, and marks paper with a more brilliant ſtroke; and, as it reſembles no other ſubſtance, it does not require to be aſſayed. Diſtinctive characters.

CHAP. XVIII.

CONCERNING URANITE, OR URANIUM.

METALLIC SUBSTANCES.

Uranite, or uranium.

THE celebrated profeſſor Klaproth has detected a new metallic ſubſtance in the mineral uſually diſtinguiſhed by the name of pech-blende, or pitch-blende, and ranged among the ores of zinc. As it is not reducible but with the moſt extreme difficulty, and then only into minute grains, it appears of little conſequence to enter into any formal deſcription of its metallic ſtate: for which reaſon, I ſhall follow the order of the profeſſor's analyſis in the preſent chapter*.

Deſcription of pitch-blende.

The pitch-blende, or ore of uranite, is found in maſſes, or elſe ſtratified with other earths or minerals, in the Swediſh and Saxon mines. It conſiſts of two varieties: the firſt in maſſes of a blackiſh colour, inclining to a deep ſteel grey, of little brilliancy; its fracture is unequal and concave in the ſmalleſt parts. It is perfectly opake, conſiderably hard, and becomes convertible into a black powder by trituration. Its mean ſpecific gravity is about 7.5. The ſecond variety is uſually found in ſtrata, and is diſtinguiſhed from the former by a deeper black colour, intermixed with ſpots of red; its colour is more ſhining, and

* Journal de Phyſique, April 1790.

approaches

approaches that of coal; it is lefs hard, and, when pulverized, it has a greenifh tinge.

METALLIC SUBSTANCES.

Habitudes by fire.

This mineral fuffers no change before the blow-pipe. With mineral alkali it affords a a fpongy, femi-opake, grey globule. With microcofmic falt it melts, and affords a green tranfparent globule; and in both there are fometimes feen fmall globules of reduced lead. When the mineral is heated alone, in a proper veffel, it gives out fulphureous acid and fulphur, with lofs of weight; but if it be afterwards kept ignited for a confiderable time beneath a muffle, it gains fome weight by calcination.

Action of acids on pitch-blende.

The vitriolic acid acts very imperfectly upon pitch-blende; but nitrous acid completely decompofes it, holding moft part in folution, while a fmall proportion of fulphur, and fome filiceous earth, fall down. Marine acid acts but imperfectly upon it; but aqua regia diffolves it, as well as the pure nitrous acid. This folution, after it had depofited a fmall quantity of corneous lead, afforded large tranfparent cryftals by repofe in the cold, which were of a faint yellowifh green colour, and of a figure not eafy to be afcertained.

Precipitates.

It was remarkable, that this fubftance was not precipitable from its folvents either by iron or zinc; but volatile liver of fulphur threw down a brownifh yellow precipitate. Nut-galls did not precipitate any thing, unlefs the fuperabundant acid were neutralized by an alkali; and, in this cafe, the precipitate by galls was of a chocolate brown.

Precipitates.

A diftinctive criterion of this metallic fubftance was, its brownifh red colour when feparated by Pruffian

6 alkali;

METALLIC SUBSTANCES.

alkali; a circumſtance indeed common alſo to copper: but this laſt metal falls down in flocks, whereas the former is uniformly ſeparated through the whole fluid. Volatile alkali uſually precipitates it of a yellow colour, more or leſs obſcure, according to the purity of the mineral, or of the alkali. The two fixed alkalis, when pure, precipitate it completely in the form of a lemon-coloured calx. Mild alkalis afford a paler calx.

Yellow calx of pitch-blende.

The yellow precipitate is very ſoluble in acids, and affords cryſtals by combination with the vitriolic and acetous acids. Phoſphoric acid affords yellowiſh irregular flocks, ſparingly ſoluble in water. Alkalis do not diſſolve the yellow matter either in the dry or humid way.

Reduction.

Various attempts were made by the diſcoverer to revive it to the reguline ſtate. He triturated it with linſeed oil to the conſiſtence of a paſte, burned the oil in a roaſting teſt, then placed the remaining black powder in a crucible lined with charcoal, and well covered, and expoſed it to a violent heat; which operated a reduction of manganeſe in another crucible, but produced no other change in the calx of uranite than to render it ſoluble in nitrous acid, with effervеſcence, heat, and eſcape of nitrous air. This altered calx was then put into an aſſayer's teſt, covered with borax, and mixed with charcoal, and the lid luted on. The heat of a porcelain furnace reduced it into a coherent maſs, conſiſting of very ſmall metallic globules agglutinated together.

BOOK II.

PARTICULAR CHEMISTRY.

SECTION IV.

OF MINERAL COMBUSTIBLE BODIES, AND THE DIAMOND.

CHAP. I.

OF MINERAL COMBUSTIBLE BODIES.

MINERAL COMBUSTIBLES. Enumeration.

THE inflammable ſubſtances found in the mineral kingdom are—1. Inflammable air, called fire-damp in the mines. 2. Hepatic air, which abounds in many hot baths, in mines, and in the neighbourhood of volcanos. 3. Naptha; a fine, thin, fragrant, colourleſs oil, which iſſues out of white, yellow, or black clays in Perſia and Media. This is highly inflammable, and is not decompoſed by diſtillation. It diſſolves reſins, and the eſſential oils of thyme and lavender; but is not itſelf ſoluble either in ſpirit of wine

MINERAL COMBUSTIBLES.

Petroleum.

wine or æther. It is the lighteſt of all the denſe fluids; its ſpecific gravity being 0.708. 4. Petroleum, which is a yellow, reddiſh, brown, greeniſh, or blackiſh oil, found dropping from rocks, or iſſuing from the earth, in the duchy of Modena, and in various other parts of Europe and Aſia. This likewiſe is inſoluble in ſpirit of wine; and ſeems to conſiſt of naptha, thickened by expoſure to the atmoſphere. It contains a portion of the acid of amber.

Barbadoes tar.

5. Barbadoes tar, which is a viſcid, brown, or black inflammable ſubſtance, inſoluble in ſpirit of wine, and containing the acid of amber. This appears to be the mineral oil in its third ſtage of alteration.

Aſphaltum.

6. Aſphaltum is a ſmooth, hard, brittle, inflammable ſubſtance, which melts eaſily, and burns without leaving any aſhes, if it be pure. It is ſlightly and partially acted on by ſpirit of wine and æther.

Mineral tallow.

7. Mineral tallow, which is a white ſubſtance, of the conſiſtence of tallow, and as greaſy, though more brittle. It was found in the ſea on the coaſts of Finland, in the year 1736; and is alſo met with in ſome rocky parts of Perſia. It is near one-fifth lighter than tallow; burns with a blue flame, and a ſmell of greaſe, leaving a black viſcid matter behind, which is more difficultly conſumed.

Jet.

8. Jet, which is much harder than aſphaltum; ſuſceptible of a good poliſh, and glaſſy in its fracture. It is highly electrical, fuſible in a moderate heat, and inſoluble in ſpirit of wine.

Pit coal.

9. Pit coal. Of this there are many varieties: they appear to conſiſt of petroleum, conſolidated with an earth, chiefly of the argillaceous kind.

Peat.

10. Peat is a black inflammable earth, which is of a viſcid conſiſtence

ence when fresh, but hardens by exposure to the air. 11. Turf consists of mould, interwoven with the roots of vegetables. 12. Amber has been already treated of (204). It is insoluble in water, and in spirit of wine; and no other acid but the vitriolic dissolves it. By distillation it affords a small portion of water, an oil of the nature of petroleum, and a peculiar acid. 13. Sulphur is very abundant in the mineral kingdom. It has before passed under our observation, on account of its affording the vitriolic acid by combustion. 14. Plumbago, or black lead.

MINERAL COMBUSTIBLES.

Turf. Amber.

Sulphur.

Plumbago.

General observations on the combustible substances found in the mineral kingdom.

When we attend to the inflammable substances found in the earth, or in the mineral kingdom, we may perceive that very few, and most probably none of them, can be truly said to belong to it; but have been elaborated in the bodies of animals or vegetables. From the turf that is pared from the surface of the earth, and owes its inflammability to the roots of vegetables which are mixed with it, we may descend to the peat, or black earth, of the moors; in many specimens of which, vegetable remains are still perceptible; though in most they appear to be deprived of every appearance of their organic texture, their oily and inflammable nature only remaining: and from thence the transition to pit-coal is easy. For if we reflect on the vast revolutions which the earth has certainly undergone through a long course of ages, by means of which its surface has been broken, displaced, and inverted, from the actions of floods, earthquakes, and the great convulsions of nature caused by volcanic eruptions, it will be no improbable inference, that the thin, though extensive, strata of pit coal, as well as the

MINERAL COMBUSTIBLES.

General obfervations on the combuftible matter found in the mineral kingdom.

the exfudations of naptha, petroleum, and their modifications, have all arifen from the burying of extenfive woody tracts of the furface, fuch as are common in all uncultivated countries. And this probability will be reduced to a certainty, when we advert to the natural hiftory of pit coal, which is met with in all the various ftates of transformation. Whole trees are converted into pit coal, in fuch quantities together as to exhibit entire forefts; in which the roots, trunks, branches, bark, and even fpecies, are difcernible. Coal-pits and flate-quarries exhibit innumerable marks of impreffions of leaves, and other indications of their vegetable origin; and the analyfis of this combuftible fubftance tends ftill further to confirm this truth. On the other hand, if we attend to fuch inferences as chemical theory might point out from the facts around us, we fhall fee how fmall the probability is, that the mineral kingdom fhould, after a certain limited time, contain inflammable bodies, if they were not occafionally thrown into it, in confequence of the operations carried on within organized fubftances. For all inflammable fubftances, tending to decompofe the vital air of the atmofphere, would, in procefs of time, revert to the clafs of uninflammable bodies, if the operation of organized bodies, particularly of the vegetable kind, did not tend to difengage the vital air again, and render bodies combuftible, which were not fo when they became parts of thofe fubftances.

CHAP.

CHAP. II.

CONCERNING THE DIAMOND.

DIAMOND. Characters, &c. of the diamond.

THE diamond is a mineral which, on feveral accounts, appears worthy to compofe an order by itfelf. It is found in a fandy earth in the hither peninfula of India, in the ifland of Borneo, and in the Brazils. The form of the diamond, when perfect, is that of an eight-fided prifm. There are alfo cubical diamonds, which are fufpected to be of a different nature from the others. Diamonds are of a lamellated texture; and may be eafily fplit by a blow in a proper direction. The confent of mankind has fixed an immenfe value upon this ftone *. The inimitable qualities to which this preference is attached, are its hardnefs,

* The value of diamonds is reckoned by weight, at fo much the carat. The carat ufed in this valuation is divided into four parts, called grains; but lefs than troy grains by one fifth: for 150 carats are equal to the troy ounce of 480 grains Rough diamonds, without any flaw or blemifh, are valued at two pounds fterling the fingle carat; and the expence of cutting amounts to $3\frac{3}{4}$ pounds the carat. The value is greatly diminifhed if the diamond be imperfect, or of a bad figure; and it increafes rapidly with the fize. To find the worth of a rough diamond, its weight in carats muft be fquared, and multiplied by two, and the product will be pounds fterling. A cut or finifhed diamond is worth four times as much as one that is ftill rough. Thofe of the greateft brilliancy are fometimes valued at a higher rate; but this value has never been applied to ftones of

DIAMOND. Hardneſs and brilliance of diamonds:

hardneſs, which is ſuch that it eaſily cuts all other ſubſtances, and takes a moſt exquiſite and laſting poliſh; and its very great refracting power, which is ſuch as to occaſion all the light to be reflected which falls on any of its interior ſurfaces at a greater angle of incidence than $24\frac{1}{4}$ degrees. Hence its luſtre, when cut into the form of a regular ſolid, is very great. This may be eaſily underſtood, when it is conſidered that an artificial gem of glaſs does not reflect the light from its hinder ſurface, until that ſurface is inclined in an angle of 41 degrees. The diamond therefore will not only throw back all the light which an artificial gem would reflect, but likewiſe one half as much more; which, falling between the angles of 41 deg. and $24\frac{1}{4}$, would have been ſuffered to paſs through by the falſe gem. It is not ſurpriſing therefore that the effect of the diamond ſhould be ſo much greater; more eſpecially when we attend to its extreme tranſparency, and the accuracy of its poliſh.

—ſoluble in vitriolic acid:

No ſolvent but the vitriolic acid has any effect on this gem; in which if diamond powder be triturated, and evaporation carried on nearly to dryneſs, the acid grows black, and depoſits pellicles that burn, and are entirely conſumed. In a heat ſomewhat greater than is required to melt ſilver, the diamond is entirely volatilized, and conſumed with a ſlight flame; diminiſhing common air, and leaving a ſoot behind.

—combuſtible.

of exceſſive magnitude. It does not appear that any ſum exceeding one hundred and fifty thouſand pounds has been given for a diamond.

See Magellan's improved edition of Cronſtedt's Mineralogy, for a conſiderable maſs of entertaining information on this ſubject.

Diamonds

DIAMONDS. Coloured diamonds.

Diamonds are of all colours: the clear tranſparent ſtones are the moſt eſteemed; and, next to them, thoſe of a deeper tinge. Whether theſe coloured ſtones be really of the ſame nature as the clear diamond, has not been aſcertained. The lapidaries reckon them to be diamonds from their hardneſs and luſtre.

BOOK II.

PARTICULAR CHEMISTRY.

SECTION V.

CONCERNING THE PRODUCTS OF THE VEGETABLE KINGDOM.

CHAP. I.

OF THE STRUCTURE AND COMPONENT PARTS OF ORGANIZED SUBSTANCES.

ORGANIZED SUBSTANCES. General obfervations.

A VARIETY of changes takes place among the great mafs of minerals which come under our obfervation near the furface of the earth. Thefe, confidered individually, appear to be effected chiefly by virtue of the chemical attractions or affinities, affifted by thofe variations of pofition and of temperature which arife from external caufes; fuch as the folar light, or the alterations which the capacities of other bodies undergo. But in vegetables and animals there

The parts of organized bodies constitute apparatus for performing chemical operations.

is an exprefs organization of parts, which evidently appears to have been defigned by the Supreme Intelligence for the purpofe of uniting the powers of mechanifm to thofe of chemiftry. It does not immediately coincide with our prefent intention, to take any notice of fuch effects as are produced by the mufcular exertion of animals, or any part of their ftructure, except fo far as they modify the chemical proceffes carried on within them. In this point of view, we may confider the folid or confiftent parts of vegetables and animals as compofing an apparatus for performing a number of chemical proceffes with the fluids that circulate through them. It is true indeed that this whole feries of operations is, for the moft part, performed with fuch a minute fet of veffels; at the fame time that the bodies applied to each other, to exercife their refpective chemical attractions, feem in general to be reduced fo near their firft principles; that in the prefent ftate of our knowledge we can fcarcely proceed farther than to affert, that the effects are really produced by an application of the moft fublime chemiftry: but thefe difficulties ought rather to encourage than deprefs our attempts to arrive at a more intimate knowledge of the powers of nature.

Vegetable bodies.

The organs of vegetables appear to confift chiefly of tubes, adapted to imbibe fluid matter from the earth. This fluid, which is moftly water, rifes either by the capillary attraction, by the alternate expanfions and contractions which depend on temperature, or by other means; and depofits its impregnations during its tranfition through the veffels of the plant. The

Vegetable bodies.

The action of the folar light, the agitation produced by winds, and the nature of the circumambient air, are of great importance in thefe proceffes. It is known that vegetables do not thrive in vital air; that they abforb fixed air; and that they emit vital air during the action of light, more efpecially the ftrong light of the fun. That they emit plentiful exhalations of various kinds, is obvious from their fmell; from the humidity of countries abounding with woods; as well as from the confideration of the fhort time that would be required to dry the leaves of vegetables, if they did not conftantly receive a fupply of moifture to recruit what they muft lofe by conftant evaporation. We fee therefore that plants are affemblages of veffels, in which water and aërial fluids are received; and by fucceffive mixtures, filtrations, evaporations, or depofitions, are either decompofed, or form new compounds. Thus it may arife from the decompofition of water itfelf, that they emit vital air; while the other principle, or inflammable air, is retained, and enters into the compofition of their combuftible parts. Or, if the decompofition of water be denied, the vital air may arife from the abforption of fixed air; whofe combuftible principle (whether it be fuppofed to be inflammable air, as fome philofophers infer; or charcoal, according to others) may be retained, and anfwer a like purpofe; fince both thefe fubftances are obtained in the inflammation of vegetables.

Animal bodies.

Animal bodies are of a much more elaborate ftructure. In thefe there is a provifion for mechanically dividing folid bodies by maftication, which anfwers

ORGANIZED SUBSTANCES. Animal bodies.

the fame purpofe as grinding, pounding, or levigation, does in our experiments; namely, that of enlarging the quantity of furface to be acted upon by folvents. The procefs carried on in the ftomach appears to be of the fame kind as that which we diftinguifh by the name of digeftion; and the bowels, whatever other ufes they may ferve, evidently form an apparatus for filtering, or conveying off, the fluids; while the more folid parts of the aliments, which are probably of fuch a nature as not to be rendered fluid but by an alteration which would perhaps deftroy the texture of the machine itfelf, are rejected as ufelefs. When this filtered fluid paffes into the circulatory veffels, through which it is driven with confiderable velocity by the mechanical action of the heart, it is not only fubjected to all thofe changes which the chemical action of its parts is capable of producing, but is likewife expofed to the air of the atmofphere in the lungs, into which that elaftic fluid is repeatedly admitted by the act of refpiration. Here it undergoes a change of the fame nature as happens to other combuftible bodies when they combine with its vital part. This vital part becomes condenfed, and combines with fome principle emitted from the blood; at the fame time that it gives out a large quantity of heat, in confequence of its own capacity for heat being diminifhed. It has not been afcertained whether the fubftance which converts the infpired vital air into fixed air (of which a portion is expired from the lungs together with the noxious or phlogifticated air) be inflammable air or charcoal; and it has likewife been doubted whether any part of the vital air is abforbed by

Page 191.

by the blood. Later experiments of Dr. Prieftley fhew, however, that this laft event does actually take place *. ORGANIZED SUBSTANCES.

Secretions, or combinations of vegetable and animal fubftances.

It would lead us too far from our purpofe, if we were to attempt an explanation of the little we know refpecting the manner in which the fecretions, or combinations, that produce the various animal and vegetable fubftances, are effected; or the ufes of thofe fubftances in the œconomy of plants and animals. Moft of them are very different from any of the products of the mineral kingdom. We fhall therefore only add, that thefe organized beings are fo contrived, that their exiftence continues, and all their functions are performed, as long as the veffels are fupplied with food, or materials, to occupy the place of fuch as are carried off by evaporation from the furface, or otherwife; and as long as no great change is made, either by violence or difeafe, in thofe veffels, or the fluids they contain. But as foon as the entire procefs is interrupted in any very confiderable degree, the chemical arrangements become altered; the temperature in land animals is changed; the minute veffels are acted upon, and deftroyed; life ceafes; and the admirable ftructure, being no longer fufficiently perfect, lofes its figure, and returns, by new combinations and decompofitions, to the general mafs of unorganized matter, with a rapidity which is ufually greater, the more elaborate its conftruction.

Nutrition.

Difeafe.

Death.

The parts of vegetable or animal fubftances may be obtained, for chemical examination, either by fim-

* Phil. Tranf. lxxx. 106.

ORGANIZED SUBSTANCES.

Various methods of separating the parts of animal or vegetable fubftances.

ple preffure, which empties the veffels of their contents; by digeftion in water, or in other fluids, which diffolve certain parts, and often change their nature; by deftructive diftillation, in which the application of a ftrong heat alters the combination of the parts, and caufes the new products to pafs over into the receiver, in the order of their volatility; by fpontaneous decompofition, or fermentation, wherein the component parts take a new arrangement, and form compounds, which did not, for the moft part, exift in the organized fubftance; or, laftly, the judicious chemift will avail himfelf of all thefe feveral methods, fingly, or in combination. He will, according to circumftances, feparate the parts of an animal or vegetable fubftance by preffure, affifted by heat; or by digeftion, or boiling in various fluids added in the retort which contains the fubftance under examination. He will attend particularly to the products which pafs over, whether they be permanently elaftic, or fubject to condenfation in the temperatures we are able to produce. In fome cafes, he will fuffer the fpontaneous decompofition to precede the application of chemical methods; and in others he will attentively mark the changes which the products of his operations undergo in the courfe of time, whether in clofed veffels, or expofed to the open air. Thus it is that, in furveying the ample field of nature, the philofophical chemift poffeffes numerous means of making difcoveries, if applied with judgment and fagacity; though the progrefs of difcovery, fo far from bringing us nearer the end of our purfuit, appears continually to open new fcenes; and, by enlarging our powers of inveftigation, never fails to point out additional objects of enquiry.

Vegetable products arranged.

In treating of the products of the vegetable kingdom, we fhall attend rather to the proceffes by which we obtain them, than to any arrangement fuppofed to exift among their principles. In this way, the order will confift, firft of principles not faline, obtained in a degree of heat not exceeding that of boiling water; fecondly, faline principles, obtained by preffure, or mere folution in water or ardent fpirit; thirdly, faline principles, obtained by ftrong heat, or by the action of nitrous acid; fourthly, the products of deftructive diftillation; and, laftly, the products of fpontaneous decompofition, or fermentation.

CHAP.

CHAP. II.

CONCERNING SUCH PRINCIPLES OF VEGETABLES AS DO NOT EXHIBIT SALINE PROPERTIES, AND ARE OBTAINED WITHOUT THE APPLICATION OF ANY GREATER HEAT THAN THAT OF BOILING WATER, AND WITHOUT THE ACTION OF ANY SOLVENT BUT WATER, OR ARDENT SPIRIT.

VEGETABLE PRINCIPLES. Juices and extracts.

THOSE immediate principles of vegetables, which do not evidently exhibit ſaline properties, are called juices, when they flow out of inciſions made in the living plant, or are obtained by ſimple preſſure; and extracts, when rendered thick by evaporation of part of the water they contain. The juices of plants are purified by ſuffering their groſſer parts to ſubſide, or by filtration. In ſome caſes, the fluid is rendered clearer, by ſimply heating it in a water-bath, which cauſes part to take the form of a coagulum.

Purification.

Manipulation.

Dry plants, or woods, or ſeeds, are either raſped, pounded, or ground, to ſeparate their parts, and may be macerated, boiled, or digeſted in water, or ſpirit of wine; or the inſoluble parts may be ſubjected to preſſure, to force out their fluid contents. Theſe fluids may be purified by means ſimilar to thoſe which are applied to the expreſſed juices of plants.

The

VEGETABLE PRINCIPLES.

Enumeration of such principles of vegetables as are not saline.

The principles of plants which are not of a saline nature, and are obtained without destroying them by heat, are—1. Gum, or mucilage, which is soluble in water, but not in ardent spirit. 2. Sugar, which is soluble both in water and in ardent spirit. 3. Starch, which, though insoluble in either of these fluids, forms a paste with water, especially if heated. 4. Vegetable gluten, which is neither soluble nor diffusible in water or ardent spirit; has a tenacious consistence when recently prepared; but does not imbibe water after it has once been dried. 5. Fat oils, which are insoluble in water or ardent spirit, and are either fluid, or fusible, without alteration, by a moderate heat. 6. Volatile or essential oils, which are soluble in ardent spirit, but not in water, and rise totally in distillation. 7. Camphor, which differs from essential oils in being more concrete, more volatile, and in being totally soluble, without alteration, in concentrated acids. 8. Resins, which differ from essential oils, in being decomposable by heat; and from camphor, in being changed by acids. 9. The aromatic principle, or vegetable principle of smell. 10. Colouring matters.

Juices or extracts.

The juices or extracts of plants, in general, contain both gum and resin, which may be separated by their respective solvents, water and ardent spirit. These appear to exist together in the plant, forming a compound of a soapy or saponaceous nature.

Gum.

Gum is a substance very well known. It is usually transparent, more or less brittle when dry, and gives a thick, viscid, and gluey consistence to water in which it is dissolved. Gum is usually obtained by wounding the

VEGETABLE PRINCIPLES.

Mucilage or gum.

the trunks or branches of trees, fuch as the plum, the pear, the cherry tree, &c.; and is diftinguifhed by various denominations, according to the plant from which it is obtained. It is obfervable that faccharine fruits, when four and unripe, are found to contain gum, and an acid; whence the faccharine matter feems to be formed of thefe principles. This is rendered much more probable from the confideration that gum and fugar afford nearly the fame products by heat, or by diftillation with the nitrous acid, as we fhall hereafter fhew.

Sugar.

Sugar may be reckoned among mucilages or gums: it appears to be brought nearer to the faline ftate. Ardent fpirit diffolves it as well as water. The peculiar tafte of this fubftance indicates its prefence in a number of fruits and other vegetables; but it is moft plentifully obtained from the fugar cane, which is cultivated in warm climates. The juice of the plant is expreffed by paffing it between two cylinders of iron, placed perpendicularly. This fluid, which is thick and tenacious, is boiled together with lime and alum, and is afterwards fuffered to cryftallize by ftanding in a veffel, in the bottom of which are holes imperfectly ftopped, in order that the fyrup may drain off. The procefs of refining fugar appears to be capable of confiderable improvement. It is not clearly afcertained what effect the lime and alum have upon the procefs; but it is highly probable that a part of the fugar is burned in the boiling, and converted into an acid, which combines with the lime, and would elfe impede the cryftallization of the fugar. The coarfe fugar thus produced, is refined by fubfequent folution in water, and boiling with a fmall proportion of lime, together with

Manufacture of fugar.

with bullock's blood or eggs. These fluids, which are at first diffused through the liquor, have the property of becoming concrete, as the temperature increases, and rise in the form of skum to the surface of the fluid, carrying with them the impurities, and rendering it more clear and transparent. The filtered liquor is then either poured into moulds, in which, by a confused crystallization, it forms loaf sugar; or else it is exposed in heated rooms, where, by a gradual crystallization, it forms sugar-candy.

VEGETABLE PRINCIPLES.

Manufacture of sugar.

The habitude of sugar with water greatly resembles that of salts; but it has not been ascertained that it contains any salt ready formed, except a small proportion of alkali. It is more inflammable than gums.

Flour, or the powder of farinaceous seeds.

Flour, or the pulverized substance of farinaceous seeds, has a strong analogy to the gummy and saccharine mucilages. These seeds, if moistened, and exposed to a moderate or summer temperature, become in a great measure converted into saccharine mucilages, as happens in the process of converting barley into malt. Wheat flour may be taken as an example of the composition of these seeds, before they begin to vegetate afresh. If this be made into a paste, and washed in a large quantity of water, it is separated into three distinct substances; a mucilaginous saccharine matter, which is really dissolved in the liquor, and may be separated from it by evaporation; starch, which is suspended in the fluid, and subsides to the bottom by repose; and gluten, which remains in the hand, and is tenacious, very ductile, somewhat elastic, and of a brown grey colour. The first of these substances does not essentially differ from other saccharine mucilages.

Wheat flour washed in water.

VEGETABLE PRINCIPLES.

Starch.

lages. The fecond, namely the ftarch, forms a gluey fluid by boiling in water, though it is fcarcely, if at all, acted upon by that fluid, when cold. Its habitudes and products with the fire, or with nitrous acid, are nearly the fame as thofe of gum, and of fugar. It appears to be as much more remote from the faline ftate than gum, as gum is more remote from that ftate than fugar.

Vegetable gluten.

The vegetable gluten, though it exifted before the wafhing in the pulverulent form, and has acquired its tenacity and adhefive qualities from the water it imbibed, is neverthelefs totally infoluble in that fluid. It has fcarcely any tafte. When dry it is femi-tranfparent, and refembles glue in its colour and appearance. If it be drawn out thin, when firft obtained, it may be dried by expofure to the air ; but, if it be expofed to warmth and moifture while wet, it putrefies like an animal fubftance. The dried gluten, applied to the flame of a candle, crackles, fwells, and burns, exactly like a feather or piece of horn. It affords the fame products by deftructive diftillation as animal matters do ; is not foluble in ardent fpirit, oils, or ether ; and is acted upon by acids and alkalis, when heated.

Fat oils.

Fat oils are obtained by preffure from the emulfive feeds or kernels of vegetables : they are generally fluid in the temperature of the atmofphere, but fome of them have a confiderable degree of firmnefs or folidity. They have a very fmooth feel ; are moftly without fmell or tafte ; require a degree of heat much fuperior to that of boiling water, to caufe them to rife in ebullition ; and cannot be fet on fire, unlefs heated to this

degree.

Fat oils:

degree. The ufe of the wick of a lamp confifts in bringing fmall portions of oil to its extremity, by the capillary attraction, where they become fucceffively volatilized and inflamed. Oils are remarkably lefs fonorous than water, when poured out. Fat oils, not being at all diffipated by the heat of the atmofphere, make a permanent greafy fpot when they fall on porous fubftances.

—decompofed by diftillation:

Thefe oils are decompofed by diftillation, and afford a fmall quantity of water loaded with a peculiar acid, a light oil, a denfe oil, inflammable air, and fixed air. The refidue confifts of a fmall quantity of charcoal.

—habitudes with air, water, and various fubftances.

Fat oils, by expofure to the air, become rancid; and exhibit a difengaged acid, which may be wafhed off by water. When they are expofed to the air in a thin coat upon the furface of water, they become more confiftent, like wax, by abforbing the vital part of the atmofphere; the aërated or dephlogifticated marine acid produces this change more fpeedily. Agitation in water feparates a mucilage from them. They combine with magnefia, and with lime, which convert them into faponaceous compounds. With the pure alkalis they form common foap. They do not unite with the volatile alkali but by long trituration.

The mineral acids unite with fat oils, and form compounds, or imperfect foaps. Fuming nitrous acid caufes them to take fire, as has already been obferved. Sulphur is foluble in fat oils, by a digefting heat; and is gradually depofited in part from them, in a cryftalline form, by cooling.

Thefe fulphureous compounds are called balfams of fulphur.

Bitumens

VEGETABLE PRINCIPLES.

Bitumens and amber are foluble in fat oils, and form varnifhes.

Volatile or effential oils:

Volatile or effential oils have ufually a ftrong aromatic fmell, are fufficiently volatile to rife with the heat of boiling water, and are in general foluble in fpirit of wine. They exift in almoft all fragrant vegetables; and in the various plants they are found either in the wood, the root, the bark, the leaves, the flowers, the fruits, &c. They differ very much in the degree of fluidity they poffefs at a common temperature, and their colours are various. They are obtained either by expreffion, as from the peel of oranges and lemons, or by diftillation with water. Some effential oils, fuch as thofe of cinnamon, faffafras, and other foreign plants, fink to the bottom of the water with which they come over; others float at the top. It is eafy to diftinguifh the adulteration of volatile oils, either by pouring ardent fpirit upon them, which will not diffolve the fat oil they may be contaminated with; or if they be dropped on paper, and held to the fire, in this cafe they leave a greafy fpot behind. If oil of turpentine be fraudulently added to them, its fmell betrays its prefence when treated in this manner.

—obtained by preffure or by diftillation:

—are inflammable.

Volatile oils are very inflammable. By expofure to air, they become thick in procefs of time, and affume the character of refins.

Combinations.

They unite with difficulty to lime and alkalis. The vitriolic acid converts them into bitumens; but, if diluted, it renders them faponaceous, as does likewife the muriatic acid. Nitrous acid inflames them.

They unite very readily with fulphur, and form balfams.

ſams. Mucilages and ſugar render them ſoluble or diffuſible in water.

Camphor. Camphor is a peculiar vegetable ſubſtance, which reſembles volatile oil, and is in fact depoſited from ſome of the volatile oils by long ſtanding. It has been obtained in ſmall quantities by diſtillation with water from thyme, roſemary, ſage, and other fragrant plants. The camphor of commerce is obtained from a ſpecies of laurel, which grows in China and the Indian iſlands, by diſtillation of the wood and other parts of the tree with water. The camphor riſes by the heat, and is afterwards purified by a repetition of the proceſs, with the addition of about one-twelfth of its weight of lime.

Characters of camphor: This ſubſtance is much more volatile than eſſential oils. It cannot be preſerved without loſs, but in cloſed veſſels, and even in theſe it ſublimes by the heat of ſummer. Water does not diſſolve it; but it is plentifully ſoluble in ſpirit of wine, in ether, and in concentrated acids; from all which it is ſeparated, without alteration, by the addition of water. Fixed and volatile oils diſſolve camphor, with the aſſiſtance of heat, and depoſit cryſtals in the form of a beautiful vegetation by cooling.

—its acid. A peculiar acid is formed by diſtillation of the nitrous acid from this ſubſtance.

Reſins, how obtained. Reſins are dried juices of plants, which are of the nature of eſſential oil. They uſually flow from wounds made in the trunks of trees for that purpoſe. Fragrant reſins have been diſtinguiſhed by the name of balſams. Almoſt all the concrete juices, diſtinguiſhed by the name of reſins, are ſoluble in ardent ſpirit. Water

 diſſolves

VEGETABLE PRINCIPLES.

diſſolves none of them. They are inflammable, and burn with much ſmoke. In cloſed veſſels they do not riſe wholly by heat, like eſſential oils, but are decompoſed.

Reſinous ſubſtances.

A very conſiderable number of reſinous ſubſtances are known and uſed in the arts. Common reſin of the pine, the reſin of the fir, pitch, tar, and turpentine, are among thoſe which are ſoluble in ſpirit of wine, and are of the nature of eſſential oils. Copal, and the elaſtic ſubſtance called caoutchouc, which is the inſpiſſated juice of a tree from Africa, are uſually reckoned among reſins; though neither ſpirit of wine nor water diſſolves them. They are ſoluble however in oils, by the aſſiſtance of heat, and ſeem to be of the nature of fat oils. The juices called gum reſins are variouſly ſoluble in the different menſtruums, according to the nature and abundance of their component parts.

Principle of ſmell in vegetables.

The principle of ſmell in plants appears to be of an exceedingly ſubtile nature. It ſeems in general to reſide in the eſſential oil, and compoſes an extremely ſmall part of the weight of vegetables, as may be inferred from the loſs of fragrance ſuſtained by eſſential oils, with little or no loſs of their weight. This however does not neceſſarily ſuppoſe that the whole principle of ſmell has flown off; becauſe it may with equal probability be ſuppoſed to have entered into combination with ſome of the other principles of the ſubſtance which afforded it. Diſtillation with ſpirit of wine is uſed to extract the fragrant principle from plants. A conſiderable proportion of this matter may be obtained by diſtillation with water, in which it comes over probably diffufed with a fmall proportion of effential oil. It has been fuppofed to confift of an elaftic fluid of a peculiar nature.

VEGETABLE PRINCIPLES.

Colouring matters:

The knowledge of the colouring matters of vegetables is of great importance to fociety, as the art of dyeing depends on the application of thefe fubftances. Much however remains to be afcertained concerning them. If the doctrine of Newton were incontrovertibly eftablifhed, that the colours of bodies depend folely upon the magnitude of the integrant particles of bodies, we might affert, without hefitation, that all the principles of bodies might be applied in theory to the production of any affignable colour; and we might thence infer, that the colour of plants is not produced by the diffufion of coloured particles of any particular kind, but by the configuration of the parts taken in general. But we are not fufficiently advanced in any part of the knowledge of nature, to reafon with fafety, without conftant recurrence to the teft of experiment. In this way we find that the chemical folvents, in many inftances, deprive plants of their colour, at the fame time that they themfelves acquire it; doubtlefs by folution of the colouring matter, which they again depofit upon bodies prepared for that purpofe. Water diffolves the colouring matter of various fubftances, fuch as logwood, madder, &c. The ftuffs to be dyed require, in many cafes, the previous foaking in a folution of alum, vegetable alkali, or other falts, to prevent their giving the colour out again to water. Other colouring principles are foluble in oils, fuch as alkanet; and many which are not foluble in water, are

—are taken up by chemical folvents.

Art of dyeing.

taken up that fluid, by the intervention of an alkali. The art of dyeing, or of fixing colouring matter upon various ſtuffs, appears to depend upon the chemical affinities of the colouring matters either with the ſtuffs themſelves, or the matters in which they are previouſly infuſed. The condition required in a good dye appears to be, that the colouring matter ſhall be precipitated on the ſtuff, and form a compound not ſoluble in the liquids to which the ſtuff will probably be expoſed. Thus, for example, printed or dyed linens or cottons ought to reſiſt the action of ſoap and alkalis; and woollens ought more particularly to withſtand the action of acids, ſuch as lemons, vinegar, &c. which may accidentally fall on them.

Lakes.

Certain colours, called lakes, are prepared by diſſolving the vegetable colouring matters, and precipitating them by the addition of ſome other ſubſtance. Thus, for example, if madder be boiled in water together with an alkali, and alum be then added, the earth of the alum will be precipitated together with the colouring matter, with which it will form an inſoluble pigment.

CHAP.

CHAP. III.

CONCERNING THE SALINE PRINCIPLES OF PLANTS OBTAINED BY PRESSURE, OR BY THE APPLICATION OF WATER OR ARDENT SPIRIT; PARTICULARLY THE ACIDS OF LEMONS, OF APPLES, OF NUT-GALLS, AND OF BENZOIN.

VEGETABLE SALTS.

Mineral falts found in vegetables.

THE faline principles of plants are either fuch as are found in the mineral kingdom; namely, vitriolated tartar, Glauber's falt, nitre, common falt, and the fixed alkalis; or they are fuch as are peculiar to this kingdom. The mineral falts are fuppofed to have entered into the veffels of the plants which afford them, and to have remained there unaltered. The falts peculiar to vegetables are, for the moft part, of an acid nature. They confift of the acids of lemons and of apples, which are obtained in an impure ftate by preffure; the acid of nut-galls, and the acid of benzoin; the falts of tartar and of forrel, which contain a portion of alkali; and fuch acids as are formed by diftilling the nitrous acid from vegetable fubftances, which are thofe of fugar, camphor, cork, &c. Deftructive diftillation likewife develops or forms peculiar acids. Thofe obtained from tartar, from mucilage or fugar, and from wood, have only been examined.

Peculiar falts enumerated.

VEGETABLE ACIDS.

Various methods of preserving lemon-juice:

The juice of lemons, or limes, has all the characters of an acid of confiderable ftrength. On account of the mucilaginous matter with which it is mixed in its firft ftate, it is very foon altered by fpontaneous decompofition. Various methods have been contrived to prevent this effect from taking place, in order that this wholefome and agreeable acid might be preferved for ufe in long voyages, or other domeftic occafions.

—by oil:

The juice may be kept in bottles under a thin ftratum of oil, which indeed prevents, or greatly retards, its total decompofition; though the original frefh tafte foon gives place to one which is much lefs grateful.

—by evaporation:

In the Eaft Indies it is evaporated to the confiftence of a thick extract. If this operation be carefully performed by a very gentle heat, it is found to be very effectual. When the juice is thus heated, the mucilage thickens, and feparates in the form of flocks; part of which fubfides, and part rifes to the furface: thefe muft be taken out. The vapours which arife are not acid. If the evaporation be not carried fo far as to deprive the liquid of its fluidity, it may be long preferved in well-clofed bottles; in which, after fome weeks ftanding, a farther portion of mucilage is feparated, without any perceptible change in the acid.

—by freezing

Of all the methods of preferving lemon juice, that of concentrating it by froft appears to be the beft; though, in the warmer climates, it cannot conveniently be practifed. Lemon juice, expofed to the air in a temperature of between 50° and 60°, depofits in a few hours a white femi-tranfparent mucilaginous matter, which leaves the fluid, after decantation and filtration, much

much less alterable than before. This mucilage is not of a gummy nature, but resembles the gluten of wheat in its properties: it is not soluble in water, when dried. More mucilage is separated from lemon juice by standing in closed vessels. If this depurated lemon juice be exposed to a degree of cold of about seven or eight degrees below the freezing point, the aqueous part will freeze, and the ice may be taken away as it forms; and if the process be continued until the ice begins to exhibit signs of acidity, the remaining acid will be found to be reduced to about one-eighth of its original quantity, at the same time that its acidity will be eight times as intense; as is proved by its requiring eight times the quantity of alkali to saturate an equal portion of it. This concentrated acid may be kept for use; or, if preferred, it may be made into a dry lemonade, by adding six times its weight of fine loaf sugar in powder *.

Depuration of the acid of lemons:

—by congelation:

The above processes may be used when the acid of lemons is wanted for domestic purposes; because they leave it in possession of the oils, or other principles, on which its flavour peculiarly depends. But in chemical researches, where the acid itself is required to be had in the utmost purity, a more elaborate process must be used. Boiling lemon juice is to be saturated with powdered chalk, whose weight is to be noted. The neutral saline compound is scarcely more soluble in water than selenite: it therefore falls to the bottom; while the mucilage remains suspended in

—by the chemical affinities.

* Georgius, quoted by Fourcroy, iv. 33.

VEGETABLE ACIDS.

Depuration of acid of lemons.

the watery fluid, which muſt be decanted off. The remaining precipitate muſt then be waſhed with warm water until it comes off clear. To the powder, thus edulcorated, a quantity of vitriolic acid, ſufficient to ſaturate the chalk, and diluted with ten parts of water, muſt be added, and the mixture boiled a few minutes. The vitriolic acid combines with the lime, and forms ſelenite, which remains behind when the cold liquor is filtered; while the diſengaged acid of lemons remains diſſolved in the fluid. This laſt muſt be evaporated to the conſiſtence of a thin ſyrup; and vitriolic acid muſt be then added in ſmall portions, to precipitate the lime, if any ſhould ſtill remain in combination with acid of lemons. When no more precipitate is afforded by the addition of vitriolic acid, a farther evaporation ſeparates the pure acid of lemons in cryſtals. It is neceſſary that the vitriolic acid laſt added ſhould be rather in exceſs; becauſe the preſence of a ſmall quantity of lime will prevent the cryſtallization. This exceſs will be found in the mother water *.

Characters.

The concrete acid of lemons remains conſiſtent in the air, is very ſoluble in water, and exhibits ſtrong acid properties. Its watery ſolution is decompoſed by a ſlow putrefaction. It unites with the alkalis and earths, ſilex excepted; and forms peculiar neutral ſalts, which have not yet been much examined. Several of the metallic ſubſtances are likewiſe acted upon by it; and it would probably diſſolve all their calces.

* Scheele's Eſſays, Eng. Tranſlation, p. 361; or Crell's Journal for 1784.

The

VEGETABLE ACIDS.

Method of purifying the acid of apples.

The acid which abounds in four or unripe fruits exhibits diftinct properties. As it is plentifully obtained from apples, the firft examiner, Scheele, has denominated it the acid of apples. In order to obtain it, the juice of four apples is expreffed from the fruit, and faturated with vegetable alkali. To this liquor a folution of the vitriolic falt of lead muft be very gradually added. A double decompofition takes place. The vitriolic acid combines with the alkali, and forms vitriolated tartar; at the fame time that the acid of apples, uniting with the lead, forms an infoluble precipitate. When the precipitate nearly ceafes to fall down, the folution of fugar of lead muft be added cautioufly, by a drop at a time, until no more precipitate is afforded. The vitriolated tartar may be wafhed off from the precipitate; and diluted vitriolic acid being then poured on the precipitate, fugar of lead is again formed, and the acid of apples is fet at liberty.

Separation of the acids of lemons and of apples.

In fuch fruits as contain the acid of lemons as well as that of apples, the feparation of one from the other is accomplifhed by the following procefs. The juice of goofeberries, for example, is evaporated to the confiftence of fyrup: pure ardent fpirit being poured upon this, diffolves the acids, and leaves the mucilage, which may be feparated by filtration. The ardent fpirit being then evaporated, and water added, the acids muft be faturated with chalk. The folution being boiled for a few minutes, the calcareous falt of lemons falls to the bottom, on account of its difficult folubility; while the other falt, confifting of the acid of apples, united to lime, remains fufpended, and may confe-

VEGETABLE ACIDS.

Acid of apples.

confequently be decanted off. This neutral falt not being foluble in fpirit of wine, may be precipitated by the addition of a proper quantity of that fluid; which, at the fame time, deprives it of a portion of faponaceous and faccharine matter. The coagulum, or precipitate, which confifts for the moft part of the acid of apples, perfectly neutralized by lime, may be diffolved in boiling water. An addition of fugar of lead forms a precipitate by double affinity, as in the firft cafe, confifting of the acid of apples united to lead; and this wafhed precipitate may be decompofed by the addition of diluted vitriolic acid, which combines with the lead, and fets the acid of apples at liberty.

Characters.

This acid exhibits peculiar properties. It cannot be obtained in cryftals; and forms deliquefcent falts with the three alkalis, and alfo with magnefia. Its faline combination with lime is cryftallizable; and with clay it forms a falt of very fparing folubility. It diffolves iron, with which it forms a falt that does not cryftallize. With zinc it forms a falt which affords beautiful cryftals. It precipitates the nitrous folutions of mercury, lead, filver, and gold, in the metallic ftate: when nitrous acid is diftilled from it, it is converted into acid of fugar.

The aftringent principle.

Many vegetable fubftances, fuch as the hufks of nuts, the bark of the oak, the nut-gall, and other vegetable matters, abound with a fubftance which has been diftinguifhed by the name of the aftringent principle. Its diftinguifhing character is that of precipitating iron from its folutions in acids, of a black colour. The nut-gall is chiefly ufed for this, and other purpofes

purpofes wherein the application of this property is required; and, as it refembles acids in its properties, the principle has been called the acid of galls. VEGETABLE ACIDS.

The acid of galls is obtained by macerating the nut-gall in water. This infufion reddens turnfole and blue paper. The acid is foluble in oils, ardent fpirit, and ether. Acids diffolve it, without impairing its property of forming a black precipitate with the folutions of iron: the diftilled products of nut-galls likewife poffefs the fame property. It decompofes metallic folutions, and combines with their calces: gold and filver are precipitated by it in the metallic ftate. It acts upon and diffolves iron directly. Acid of galls obtained in folution;

To obtain the acid of nut-galls in a cryftallized form, one pound of the powder of galls muft be added to fix pounds of diftilled water, and left to digeft for a fortnight, at the temperature of between 70 and 80 degrees; after which, the fluid muft be filtered, and left to evaporate fpontaneoufly in the open air, in a ftone-ware or glafs veffel. The fluid becomes mouldy, and covered with a thick glutinous pellicle; abundance of glutinous flocks fall down; and in the courfe of two or three months the fides of the veffel appear covered with fmall yellowifh cryftals, which are likewife very abundant at the under furface of the pellicle which covers the liquor. The fluid muft then be decanted; and ardent fpirit, being poured upon the mucilaginous depofition, the cryftals and the pellicle, diffolves the falt by the affiftance of heat, without touching the mucilage; and, by evaporation of this fpirituous folution, the pure gallic acid is obtained in fmall brilliant cryftals, of a grey colour inclining to yellow. —in the cryftallized form.

This

VEGETABLE ACIDS.

Page 310.
Page 310.

General characters and habitudes of the acid of galls.

This acid, on account of its long expofure to the air, may confift either of a principle exifting in the galls, or of that principle converted into an acid. It has the following properties: It precipitates martial vitriol, and other falts of iron, of a beautiful black colour, and ftrongly reddens the tincture of turnfole: when heated, with contact of air, it fwells up, and burns, leaving a coal behind of difficult incineration: by diftillation, with a gentle heat, part of the acid comes over diffolved in the water of cryftallization: another portion fublimes undecompofed in the form of filky cryftals; and a ftrong heat feparates a few drops of oil, with fixed and inflammable air.

The acid of galls is foluble in twenty-four parts of cold water, or three of boiling water. It is much more foluble in fpirit of wine; four parts of this being fufficient at the common temperature, or one when boiling hot. With lime, magnefia, or ponderous earth, it forms falts which are foluble in water: it unites readily with the alkalis, and forms compounds, which have not been much attended to. The action of the nitrous acid converts it into the acid of fugar. This acid precipitates gold, filver, mercury, copper, iron, and bifmuth, from their folutions; but it does not affect thofe of platina, zinc, tin, cobalt, and manganefe.

Benzoin.

The fragrant refin called benzoin affords a peculiar concrete acid by fublimation, which is about one tenth of the weight of the refin itfelf, but varies in different fpecimens. This acid exifts ready formed in the benzoin; but cannot eafily be wafhed out by water,

water, on account of the refin which defends it. The beft method of obtaining it in the humid way is the following: Lime-water is made by flaking four ounces of quick-lime with twelve ounces of water; and, as foon as the ebullition is over, eight pounds more of water are to be added. Six ounces of this lime-water are to be mixed by agitation with one pound of benzoin in powder, and the whole of the lime-water is then to be added; the mixture being expofed to heat over a gentle fire for half an hour (during which time it muft be continually agitated, to prevent the powder from coagulating), is afterwards fuffered to cool, and fettle for feveral hours. The clear liquor muft then be decanted, and the refidue boiled for half an hour, with eight pounds of water; which, after fubfidence and decantation, muft be added to the clear fluid of the firft boiling. The ebullition of the refidue of the matter muft be again twice repeated, and the decanted lixiviums added to the foregoing. All thefe waters are then to be evaporated to two pounds; during which operation a fmall quantity of refin falls down When the evaporated liquor is cool, a quantity of marine acid muft be added drop by drop, with conftant ftirring, till there be no more precipitation, or till the mafs has a fourifh tafte. The precipitate is the acid of benzoin.

VEGETABLE ACIDS.

Method of obtaining the acid of benzoin in the humid way.

The rationale of the above procefs is this: The lime unites with the acid of benzoin during the ebullition: the evaporation feparates a fmall quantity of refin; and diminifhes the aqueous fluid fo much, that in the fubfequent part of the operation the acid of benzoin may fall down, and be feparated for want of a uffi-

Rationale.

Method of obtaining the acid of benzoin.

a fufficient quantity of water to diffolve it. The marine acid, which is added laft of all, feizes the lime by its ftronger affinity, and forms a foluble falt; while the acid of benzoin, which is difengaged, falls down, on account of its fparing folubility. The acid thus obtained has the form of a very fine powder. If it be required in the form of filky threads, it may be diffolved in boiling water, and ftrained through a cloth. As cold water diffolves little more than one five hundredth part of its weight, though boiling water diffolves about one twentieth of this acid, the greateft part of the acid feparates by cooling.

Its characters.

The acid of benzoin combines with the foluble earths and alkalis, and forms compounds, which have been little attended to. It is foluble in the vitriolic and nitrous acids; and may be again feparated, without alteration, by the addition of water. Its habitudes with thefe acids, particularly the latter, when heated, have not been fatisfactorily afcertained. If its nature be changed by diftillation with nitrous acid, it feems probable that it is effected with much more difficulty than is experienced with other vegetable acids.

CHAP.

CHAP. IV.

CONCERNING THE ACIDS OF TARTAR AND OF SORREL.

VEGETABLE ACIDS.

Tartar.

THE two acids which are usually found in combination with a portion of the vegetable alkali, are the acid of tartar and of wood sorrel. Tartar has for a long time been considered as one of the products of the vinous fermentation; but it exists ready formed in must, in verjuice, and is likewise obtained in other chemical processes with vegetables. However, it is obtained, for all the purposes of commerce, from wine; during the insensible fermentation of which liquid, it is gradually deposited on the sides of the casks.

Cream and crystals of tartar.

Crude tartar is seldom used in medicine or philosophical chemistry; the refined tartar is known by the name of cream, or crystals, of tartar. The purification of this salt is effected by dissolving it in boiling water, filtering, and suffering it to crystallize by cooling; the crystals are again boiled, together with an argillaceous earth, to deprive them of their impurities, which are carefully scummed off; or else with whites of eggs, which answer the same purpose. When no more scum arises, a saline pellicle is formed at the top of the liquor, at the same time that the crystallization goes forward at the bottom. This salt, after the [illegible] is washed off with cold water, is sold under the name

of

VEGETABLE ACIDS.

of cream, and cryſtals of tartar. The cream of tartar conſiſts of the minute cryſtals which are formed at the top of the liquor, and the cryſtals of tartar are formed at the bottom.

Characters of purified tartar.

The taſte of this purified ſalt is leſs vinous than that of the crude tartar. When expoſed to heat, it boils up, emits an epyrcumatic ſmell, and becomes black and coaly; a ſtronger heat in an open fire entirely diſſipates its acid part, and leaves the vegetable alkali in a mild ſtate, or combined with fixed air. Its volatile products, by a gradual fire, are water, an acid, and an empyreumatic oil, which is followed by ſome volatile alkali, and a large quantity of fixed air. Cryſtals of tartar are ſoluble in twenty-eight parts of boiling water; three-fourths of the ſalt are depoſited in cooling. If the ſolution of this ſalt be left expoſed to the air, it is very ſlowly decompoſed; mucilage is depoſited, the acid diſappears, and after eighteen months the liquid is found to contain the vegetable alkali, amounting to nearly one-fourth of the weight of the tartar. This quantity of alkali being nearly the ſame as is afforded by the incineration of tartar, is a proof that the vegetable alkali is not a product of fire, as was formerly ſuppoſed.

Habitudes.

The habitudes of tartar with clay and ponderous earth have not been aſcertained. Magneſia forms with it a ſoluble ſalt. Chalk unites with the exceſs of acid in the tartar, and ſeparates the neutral ſalt; conſiſting of the vegetable alkali, ſaturated with the tartareous acid, which is known by the name of ſoluble tartar. If the vegetable alkali be added to a ſolution of cream of tartar, in ſuch a quantity as to ſaturate it, the ſame neutral

Soluble tartar.

neutral falt, or foluble tartar, will be formed. This has a bitter tafte, and is decompofed by heat, affording the fame volatile products as cream of tartar. It is foluble in four parts of water heated to 110°, and affords cryftals which are flightly deliquefcent. Soluble tartar.

It is a curious fact, though by no means fingular in the hiftory of neutral falts, that two very foluble fubftances, fuch as the vegetable alkali, and the acid of tartar, fhould compofe a falt of fo little folubility as the cryftals of tartar; more efpecially, as the point of the greateft difficulty of folution is not that at which they are faturated, but that in which the acid fo confiderably abounds. Curious fact.

If to twenty ounces of purified tartar, diffolved in four pounds of boiling water, the pure cryftallized mineral alkali be added, until the faturation be complete, as may be judged by any additional quantity producing no effervefcence; the alkali laft added will combine with the fuperfluous acid of the tartar, and form the neutral combination called the falt of Seignette, or Rochelle falt; at the fame time that the refidue of the tartar will become converted into foluble tartar. By evaporating the liquor nearly to the confiftence of fyrup, the Rochelle falt is obtained in beautiful regular prifms, of fix or eight fides, which efflorefce in the air, and are decompofed by heat in the fame manner as foluble tartar. Manufacture of Rochelle falt.

By the fame treatment with volatile alkali, an ammoniacal tartareous falt is formed, which affords cryftals that efflorefce in the air.

If the mineral acids be added to tartar, they combine with its alkali, and form the fame falts as they Ammoniacal falt of tartar.

 would

VEGETABLE ACIDS.

would have produced by direct union with the vegetable alkali.

Tartar.

Tartar has long been an object of attention with chemiſts, and it is uſed as an acid in many of the arts. This ſalt appears to be capable of uniting without decompoſition, and forming triple ſalts with moſt of the metals.

Method of obtaining the acid of tartar:

The pure acid of tartar may be obtained by ſaturating three parts of cream of tartar with chalk or lime; the former of which combines with the ſuperfluous acid, and the latter ſeizes the whole. The calcareous tartar, which, on account of its inſolubility, remains at the bottom, is then to be well waſhed, and digeſted with about one part of vitriolic acid, together with a ſufficient quantity of water. In this manner the acid of tartar is diſengaged. The ſelenite formed by the combination of the vitriolic acid and the lime, will be ſeparated, and fall down, by evaporating the water; and the acid which remains may be cryſtallized by further evaporation and cooling.

—or otherwiſe.

Or, more ſimply, one pound of cream of tartar may be boiled in five or ſix pounds of water, and a quarter of a pound of clear and colourleſs denſe vitriolic acid may be added by little and little. When a complete ſolution is obtained, the fluid will then contain diſengaged acid of tartar, together with vitriolated tartar, or the neutral ſalt formed by the union of the vitriolic acid with the vegetable alkali. The vitriolated tartar, being a ſalt of ſparing ſolubility, will be precipitated by continuing the boiling. When the liquor is evaporated to one half, it is to be filtered; and if, upon further evaporation, any thing more is precipitated,

pitated, it muſt be filtered again. The clear liquor being then reduced to the conſiſtence of a ſyrup, and ſet by in a temperate or rather warm place, will afford fine cryſtals of tartareous acid, equal in weight to half the cream of tartar employed. If too ſmall a quantity of vitriolic acid has been uſed, part of the cream of tartar will not be decompoſed, but will ſeparate from the liquor along with the vitriolated tartar. It is better therefore to uſe too little rather than too much.

Acid of tartar.

The cryſtallized tartareous acid melts, fumes, becomes black, and burns, by the contact of ignited bodies. By diſtillation it affords an acid phlegm, a ſmall quantity of oil, and much fixed air, together with inflammable air; leaving behind a coaly reſidue, which contains neither acid nor alkali.

—its characters,

The cryſtals of tartareous acid do not change by expoſure to air; they are much more ſoluble in water than cream of tartar itſelf. This acid diſſolves clay, and forms a ſalt which, by evaporation, aſſumes a clear gummy conſiſtence, and does not deliqueſce in the air. The ſame appearance is exhibited with magneſia: with lime, it forms a ſalt which is ſcarcely at all ſoluble; a due proportion of vegetable alkali converts it into cream of tartar, which falls down if the water of ſolution be not ſufficiently abundant, but is diſſolved again if more alkali be added, ſo as to convert it into ſoluble tartar. Theſe ſynthetical operations ſhew that the tartareous acid is not altered by the proceſs of extracting it from cream of tartar.

and habitudes,

With the mineral alkali it forms the Rochelle ſalt, and with volatile alkali it forms a cryſtallizable ſalt.

 In

VEGETABLE ACIDS.

In this laſt combination there is a term at which cryſtals of ſparing ſolubility, like thoſe of cream of tartar, are formed; and in this caſe likewiſe the acid of tartar is far from being ſaturated with the alkali.

This acid is convertible into the ſaccharine acid by diſtillation with ſtrong acid of nitre: and it is converted into acetous acid by digeſtion with water and ardent ſpirits.

Salt of ſorrel:

Salt of ſorrel is a cryſtallized ſalt; ſo denominated becauſe it is obtained from the wood ſorrel, or oxalis acetoſella of Linnæus, for the purpoſes of commerce; though it may be obtained from ſome other plants. It is in white cryſtals, whoſe figure has not been well determined, on account of their minuteneſs. When it is expoſed to diſtillation in a retort, the acid is partly

—characters:

decompoſed; a conſiderable quantity of acid phlegm comes over, which is without ſmell or colour, and conſiſts of the acid itſelf, ſcarcely altered; and the reſidue affords vegetable alkali, amounting to ſomewhat more than one third of the weight of the ſalt. Expoſure to air does not alter the ſalt of ſorrel. It is very ſparingly ſoluble in cold water: but boiling water may take up one ſixth part, or more, of its weight; the quantity varying according to the ſtate and purity of the ſalt, which ſeems to vary in different ſpecimens.

—action upon various ſubſtances.

Salt of ſorrel acts upon various ſubſtances without decompoſition. With ponderous earth, magneſia, vegetable alkali, and volatile alkali, it forms triple ſalts. Lime decompoſes it by ſeizing the whole of the acid, and diſengaging the alkali. The attraction of this acid for lime is ſo ſtrong, that it cannot be diſengaged from

from it by any other acid: another procefs is therefore neceffary to be ufed for obtaining it. With this intention, the fuperabundant acid is to be faturated with volatile alkali; and into this folution muft be poured a folution of ponderous earth in the nitrous acid. The laft-mentioned acid combines with the alkalis, forming nitrous ammoniac, and common nitre, both which remain in folution; while the ponderous earth, combining with the acid of forrel, forms an infoluble compound, which falls to the bottom. This precipitate, after being well wafhed, may be decompofed by the addition of vitriolic acid, which feizes the earth, and likewife forms an infoluble combination, while the acid is fet at liberty. After decantation of the clear liquid, it muft be affayed by pouring into it a little at a time of the boiling hot folution of ponderous earth in the acid of forrel. If there be any excefs of vitriolic acid, a precipitate will be formed by its union with the ponderous earth. A due evaporation and cooling of this liquor afford the acid of forrel, in prifmatic four-fided cryftals or fquare plates. Method of purifying the acid of forrel.

This acid has a confiderable degree of ftrength. Expofed to heat in a retort, it falls into powder, with the lofs of three-tenths of its weight, after which it melts, boils up, at the fame time that its colour changes to a brown. An acid phlegm comes over, and part of the acid fublimes without alteration. Fixed air and inflammable air are difengaged during this decompofition of the acid; and their quantity is greater, the more violent the heat. Characters.

Boiling water diffolves its own weight of this concrete acid falt, half of which is feparated in cryftals Combinations.

 by

VEGETABLE ACIDS.

Combinations of the acid of forrel.

by cooling. It diffolves clay, and affords a deliquefcent mafs by evaporation. With ponderous earth it forms a falt fcarcely foluble, except there be an excefs of acid; in which cafe it affords tranfparent cryftals, which become opake, powdery, and infoluble, when the excefs of acid is taken up by boiling water. With magnefia, it forms a white powdery falt; and with lime it forms an infoluble compound, which cannot be decompofed in the moift way, becaufe the affinities of thefe two fubftances are ftronger than any which exift between either of them and other known bodies. From this property, the acid of forrel is ufed as the teft of the prefence of lime, which it precipitates from all its combinations.

Synthefis.

If vegetable alkali be gradually added to a folution of this acid in water, a precipitate falls down, which is the falt of forrel, and contains the acid in excefs. A farther addition of alkali faturates the acid, and forms a very foluble falt, which is capable of cryftallizing, if the alkali be in excefs. With an excefs of the mineral alkali it forms a falt of fparing folubility. With volatile alkali it affords a cryftallizable falt; and with both thefe alkalis, if the acid be in excefs, it forms a lefs foluble falt, fimilar to what happens with the vegetable alkali.

It acts on feveral of the metals directly, but in general combines more readily with their calces.

This acid does not differ from the acid of fugar. Treatment with nitrous acid converts it into acetous acid and fixed air; or totally into the latter, if the action be rapid.

CHAP.

CHAP. V.

CONCERNING THE VEGETABLE ACIDS PRODUCED OR DEVELOPED BY DESTRUCTIVE DISTILLATION, OR BY THE ACTION OF NITROUS ACID.

VEGETABLE ACIDS: ARTIFICIAL.

Confiderations on the compofition and decompofition of vegetable bodies.

IN the courfe of the preceding accounts of the vegetable acids, it may be obferved, that they are all fubject to great alterations by the action of chemical agents; and they are all fubject to fpontaneous decompofition. They feem to obtain their acid properties by the combination of a bafe with the vital part of the air, in the fame manner as has been more fully fhewn with regard to the mineral acids; but they appear to be of too compounded a nature to retain the order or arrangement of their component parts through thofe great varieties of temperature to which in general the mineral acids may be fubjected. Heat alters the arrangement of their component parts, and feparates them from each other in a new form. The products of all vegetable fubftances, including thefe acids, are found, when urged by fire, to be water, fixed air, inflammable air, oil, coal, and alkali. If we confider water as decompofable, and confifting of vital and inflammable air; if we confider oil as compofed of fixed air and inflammable air; and again, whether we admit charcoal to confift chiefly of inflammable air, according to the opinion of fome chemifts, or of the

VEGETABLE ACIDS: ARTIFICIAL.

Simplicity and fmall number of vegetable principles.

the peculiar bafis of fixed air, according to others; and, laftly, if fixed air be allowed to confift of charcoal united to vital air, whether the charcoal be conceived as a peculiar fubftance, or as inflammable air in a ftate of condenfation; we fhall at length find that the component parts of vegetables are very few; infomuch that, if the foregoing pofitions were clearly eftablifhed, they would confift either of charcoal, vital air, and inflammable air, or elfe of vital air and inflammable air only. From the various proportions of thefe, in different ftates of condenfation, it would follow, that water, fixed air, oils, mucilages, and acids, are produced; and that the beautiful variety of nature arifes from this arrangement and combination.

Empyreumatic acids.

The firft action of fire upon the vegetable acids does not in general alter their combinations fo much, but that fome other acid comes over together with the elaftic products. Thefe acids, which on account of the peculiar fmell which they obtain from the fire are called empyreumatic, would probably, on examination, be found to be of various kinds. Thofe which have hitherto engaged the attention of chemifts, are the empyreumatic acid of tartar; the empyreumatic acid of fugar or mucilage, formerly called fpirit of honey; and the empyreumatic acid of wood, which is fuppofed to be the fame in all woods, and has been diftinguifhed by the name of fpirit of box.

Empyreumatic acid of tartar.

The empyreumatic acid of tartar is the acid phlegm which comes over when cream of tartar is expofed to diftillation. This acid is impure, on account of fome oil which comes over with it, and from which it can only

VEGETABLE ACIDS: ARTIFICIAL.

Empyreumatic acid of tartar:

only be feparated by the funnel; becaufe it dilates fo fuddenly, when an attempt is made to rectify it by a fecond diftillation, that it burfts the veffels. The acid properties of this fluid are fufficiently apparent, though it does not redden the tincture of violets, as it does turnfole and blue paper. It forms peculiar compounds with the earths and alkalis, which have not been much examined, but are very different from thofe afforded by the acid of tartar.

—of fugar or mucilage:

When infipid gummy faccharine or farinaceous mucilages are expofed to diftillation, an empyreumatic acid comes over, of a reddifh yellow colour, and a bitter, acrid, and four tafte. By rectification with the addition of clay, the acid comes over clear, and lefs empyreumatic. It does not afford cryftals, but may be concentrated by freezing, which converts its aqueous part into ice. In this ftate it ftrongly reddens blue vegetable colours, and forms a red fpot where it falls on the fkin. By diftillation, cautioufly managed in clofe veffels, it may be converted for the moft part into fixed and inflammable air.

The empyreumatic acid of fugar attacks and diffolves the foluble earths and alkalis. It corrodes lead, copper, tin, and iron: but the compounds it forms with thefe bodies have been little attended to.

—of wood.

Box, birch, and other woods, when expofed to diftillation, afford that peculiar acid which is fo offenfive to the eyes when the fmoke of a fmothering wood fire forces itfelf into an apartment. This acid has confiderable ftrength. The oil which comes over with

VEGETABLE ACIDS: ARTIFICIAL.

Acid of wood.

with it, may be feparated, either by ftanding for fome months, or by rectification. It cannot be obtained in a concrete form. A ftrong heat decompofes it. With earthy and alkaline bafes it forms peculiar falts, whofe general properties have not been minutely enquired into. As the properties of the acid obtained from a confiderable variety of woods have proved to be the fame, it is prefumed that all woods contain this common acid, or at leaft that combination of principles which conftitutes its bafe.

Obfervations on the effect of nitrous acid upon vegetable bodies.

Since the acidification of combuftible fubftances is evidently produced by the application or combination of vital air; and as, in all the operations of chemiftry, effects may be produced by one mode of combination, which are impracticable in others; it becomes neceffary, in chemical refearches, to try every means which can be devifed. Few vegetable acids are artificially produced by the direct application of vital air to the principles of that clafs of bodies; but many experiments have been made by abftracting the nitrous acid from vegetables by diftillation. This acid, as we have frequently had occafion to obferve, is very eafily decompofed, when applied to combuftible bodies, which attract its vital air, and difengage either nitrous or phlogifticated air, as we have explained in our chapter upon that acid. It has likewife been obferved, in various parts of the prefent fection, that this acid, when repeatedly diftilled from gums, mucilages, fugar, the acids of tartar, of apples, and of gall, produces the peculiar acid which has been called the acid of fugar; and, if the abftraction be repeated too often, the acid of

Chap. iii. iv.

VEGETABLE ACIDS: ARTIFICIAL.

The progrefs of acidification in vegetable bodies.

of fugar itfelf is converted into fixed air. From this view of the fubject, together with other facts, it has been inferred, that a greater or lefs proportion of vital air, united with one general principle abundantly exifting in charcoal, whether this principle be inflammable air or not, produces all the various acids of vegetables. Thus tartar, which is the leaft acidified, is faid to become converted into the acid of apples by treatment with nitrous acid. The acid of apples, by a continuance of the operation, becomes converted into acid of fugar, or acid of forrel, which are the fame thing. The fame procefs, further continued, affords vinegar *, which comes over. Hence it fhould feem that, according to the greater progrefs of the operation of combuftion, or the combination of vital air with the bafe (which at the fame time, according to the ancient theory, is fuppofed to be more dephlogifticated), the acids of tartar, of apples or unripe fruit, of forrel or fugar, of vinegar, and, laftly, of fixed air, are produced. In this order of proceeding, the acids become more and more perfect, and lefs eafily decompofable: and on this account probably it is, that attempts to reverfe the proceffes have not hitherto been attended with much fuccefs.

Difference between the acids of fugar and forrel.

Since the difcovery that the acid of fugar does not differ from that of forrel but in containing a fmall proportion of alkali, the procuring of the former in the expenfive way of diftillation with nitrous acid, is

* See Scheele's Effays, Englifh tranflation, page 385; and the Journal de Phyfique for January 1788, page 59.

become

VEGETABLE ACIDS: ARTIFICIAL.

become unneceffary. We fhall, neverthelefs, defcribe the procefs here, as an example of that method of operating.

The procefs for converting fugar into an acid.

Three ounces of ftrong nitrous acid, whofe fpecific gravity was nearly 1.567, were mixed in a tubulated retort with one ounce of the fineft fugar in powder. Much nitrous air efcaped in red fumes, formed by combination with the vital air of the atmofphere. A receiver was then adapted, and the liquor gently boiled. As foon as the mixture had acquired a dark brown colour, three additional ounces of nitrous acid were added, and the boiling was continued until the coloured and fuming acid had entirely difappeared. The liquor being then poured out, afforded fmall prifmatic cryftals by cooling, which are the acid of fugar. The lixivium, being again treated in the fame manner with two ounces of nitrous acid, afforded an additional portion of acid of fugar by cooling; and the remaining glutinous liquor, treated at different times with fmall quantities of nitrous acid, amounting in the whole to two ounces, and evaporated to drynefs, afforded a faline mafs: and, laftly, the whole was depurated by repeated folutions and cryftallizations in water. In this way, with three parts of fugar, and thirty of nitrous acid, the quantity of one part of acid of fugar is obtained.

Obfervation.

The above procefs is taken from Bergman: but it may be obferved that weak nitrous acid, or common aqua fortis, will anfwer the purpofe as well as the concentrated acid; and that, where it is not an object to collect the acid which comes over, there will be no need of any receiver, or other apparatus, except a

5 matrafs,

matrafs, or Florence flafk, to perform the operation in a chimney where there is a proper draught of air to carry off the acid fumes. VEGETABLE ACIDS: ARTIFICIAL.

Acid of camphor.

The acid of camphor * is produced by diftilling the nitrous acid eight fucceffive times from camphor. It is of a concrete cryftalline form, of a bitter tafte, and reddens the tinctures of violets and turnfole. It differs from the acid of fugar in not feparating lime from the marine acid. With vegetable alkali it forms a falt in regular hexagons; with mineral alkali, a falt in irregular cryftals; with volatile alkali, prifmatic or needle-formed cryftals; and with magnefia, a pulverulent foluble falt. It diffolves feveral metallic fubftances. But fubfequent enquiries are wanting to eftablifh the peculiar nature and properties of this acid.

Acid of cork.

By diftilling four times its weight of nitrous acid from cork, a yellowifh thick acid matter is obtained, which is foluble in water, and has an auftere bitterifh tafte. It does not cryftallize, but becomes confiftent like wax by evaporation; is foluble in ardent fpirit; forms deliquefcent falts with the earths and alkalis; and has as ftrong an attraction for lime as the acid of fugar †.

* Kofegarten, Nouv. de la Republ. des Lettres, Année 1785, Nos. 42 and 44; quoted by Fourcroy, Elem. Chem. iv. 104, edition of 1789.

† Brugnatelli, in the Journal de Phyfique, Auguft 1787; or Crell's Annals for the fame year.

CHAP.

CHAP. VI.

ON THE DESTRUCTIVE DISTILLATION OF VEGETABLE SUBSTANCES.

VEGETABLE PRODUCTS BY FIRE.

Deftructive diftillation.

IN the foregoing chapters we have occafionally treated of the decompofition of vegetables by deftructive diftillation, and have defcribed the volatile products it affords. As the immediate principles of organized fubftances are for the moft part very compounded, and the extreme temperature produced in this method tends to reduce them to their primary component parts, it is evident that very little can be learned in this way concerning that on which the various properties of thofe fubftances depend. But as the chemift ought to neglect none of the methods he poffeffes of producing changes in bodies, this procefs may have its ufe when compared with others, and more efpecially when we fhall have arrived at that knowledge of the firft principles of organized fubftances, which from a variety of facts, and the late rapid progrefs of chemiftry, we have reafon to hope for. We fhall therefore proceed to defcribe the general phenomena of deftructive diftillation.

This procefs confifts merely in expofing any organized fubftance to heat in a retort, placed in a reverberatory furnace. The ancient chemifts, who paid no attention to the elaftic products, except fo far as their

their expanſive force impeded their operations, uſually drilled a ſmall hole in the upper part of the receiver for their eſcape. Modern chemiſtry proceeds in a more ſcientific manner, by uſing the pneumatic apparatus, fig. 21. The firſt product which comes over in the diſtillation of vegetables, is a watery fluid, containing acid and odorant principles. In proportion as the deſtruction of the vegetable proceeds, the phlegm becomes deeper coloured, and more ſaline. Next follows a coloured oil, which becomes of a darker hue as the diſtillation proceeds, and varies greatly according to the nature of the plant; for it conſiſts chiefly of the eſſential oil, which comes over in a foul ſtate, and differs in its fixity, denſity, fuſibility, and all its other properties according to the nature and quantity of the eſſential oil which predominates in it. All the products obtained in this way have a peculiar burned ſmell, which chemiſts diſtinguiſh by the name of empyreumatic. If the vegetable contain volatile alkali, or its component parts, this ſubſtance uſually ſublimes when the oil comes over. The elaſtic fluids which paſs into the apparatus of inverted veſſels are chiefly inflammable air, or fixed air, or a mixture of both (probably in combination), which is heavier than pure inflammable air, and burns with a lambent blue flame, inſtead of detonating like that elaſtic fluid. The heat muſt be very gradually raiſed, and the receivers changed from time to time, in this method of decompoſition; otherwiſe the products which come over will be confounded together, and the reſults will of courſe be more fallacious than they would otherwiſe have been. The fixed reſidue conſiſts of charcoal, a ſmall

Decompoſition of vegetables by fire.

VEGETABLE PRODUCTS BY FIRE.

ſmall portion of alkali, and a very minute quantity of earth.

Empyreumatic oils.

The empyreumatic oils which come over in theſe diſtillations, may all be rendered colourleſs, and ſoluble in ardent ſpirit by rectification. In this manner it appears therefore that the fixed oils of vegetables are converted into volatile or eſſential oils; from which, as well as from other circumſtances, it is rendered probable that theſe oils differ from each other only in the proportion of their component parts.

Charcoal:

The black, ſonorous, brittle, light ſubſtance, called charcoal, uſually retains the figure of the vegetable from which it was produced, unleſs the greater part of the vegetable conſiſted of fluids, which, in their diſſipation, deſtroy the connection of the more fixed parts. In the latter caſe the quantity of charcoal is much leſs than in the former. It is a ſingular fact, that this ſubſtance, when well burned, is a perfect conductor of electricity; though the electric matter is not conveyed at all through wood which is ſimply baked or dried. The charcoal of oily or bituminous ſubſtances is of a light pulverulent form, and riſes in ſoot. This charcoal of oils is called lamp-black.

—conducts electricity:

—reſiſts heat, and abſorbs elaſtic fluids:

Charcoal reſiſts the moſt violent heat in cloſed veſſels. If it be ignited, it abſorbs elaſtic fluids with great avidity as it cools; and it retains the property if cooled by immerſion in mercury, the abſorption being equally conſiderable when it is afterwards expoſed to the air.

—exceedingly combuſtible.

The diſpoſition to be burned, which in the ancient theory is ſuppoſed to conſiſt in the giving out of phlogiſton, and in the modern theory in the abſorption

Charcoal.

ſorption of vital air, is ſo great in charcoal, that it performs the reverſe of combuſtion with a great variety of ſubſtances. Thus it converts the vitriolic acid into vitriolic air, by augmenting the proportion of ſulphur; and it is ſtrongly acted on by the nitrous acid, much nitrous air being extricated at the ſame time. The rapidity with which the nitrous acid acts upon perfectly dry charcoal, has been already mentioned. In either of theſe proceſſes, the acid either combines ſuddenly with the phlogiſton of the charcoal, or the vital air of the acid combines with the charcoal itſelf, conſidered as a ſimple ſubſtance.

Page 171.

The moſt violent combuſtion of nitre with charcoal, in which the acid is entirely decompoſed, and gives out phlogiſticated air, may be explained in the ſame way by each theory.

Solubility of charcoal.

Alkalis diſſolve charcoal in the dry way; and liver of ſulphur combines very readily with it, either in the dry or humid way. All the metallic ſubſtances hitherto known, are leſs combuſtible than charcoal, and conſequently are revived, or reduced to the metallic ſtate, by being heated with this ſubſtance. This, in the ancient theory, denotes that all the metals attract phlogiſton more ſtrongly than charcoal does; but in the new theory the effect is aſcribed to the ſtronger attraction of charcoal, which deprives all metallic calces of the vital air which combined with them during their calcination.

Revivification.

Obſervation.

An important conſequence ſeems to follow from this circumſtance; namely, that there may exiſt many metallic ſubſtances whoſe combuſtibility may be greater than that of charcoal; and which conſe-

VEGETABLE PRODUCTS BY FIRE.

quently are unknown to us as fuch, becaufe we poffefs no means of reducing them. Thus the alkalis and earths may confift of peculiar combuftible or metallic fubftances, either dephlogifticated, or combined with vital air, by an union which the art of chemiftry has not yet found means to break.

Combuftion of charcoal.

When charcoal is expofed to heat in open veffels, it burns with a light flame, nearly tranfparent, emitting very little light, and no fmoke. The refidue confifts of a fmall quantity of afhes, which contain fixed alkaline and neutral falts. The fixed vegetable alkali is obtained from the afhes of various plants, under the name of pot-afh or pearl-afh, and is not eafily purified from the neutral falts it may be contaminated with. Mineral alkali is obtained by incineration only from marine plants. The neutral falts found in the afhes of vegetables are vitriolated tartar, Glauber's falt and felenite, common falt, and falt of Sylvius. Calces of iron and of manganefe, with an earthy fubftance, compofe the infoluble refidue. What this earthy fubftance is has not been determined; but it moft probably confifts of fome infoluble earthy falt, fuch as phofphorated lime.

Refidual falts.

Spontaneous combuftion of coaly matter and oil.

A variety of inftances of combuftion have been obferved to take place in the mixture of coaly matter with oils. Whether thefe arife from the operation of vital air previoufly abforbed from the atmofphere by the coal, or from the decompofition of water which is prefent in thefe experiments, or from a mere change of capacity, by which the new combination may give out heat enough to ignite the mafs, muft remain for future refearches. The fubject however is fo generally

generally interefting, as to admit of an enumeration of fome of the facts in this place. The following are taken from M. Bucholz's paper *, in vol. i. of the Chemical Annals, by Dr. Hopfon in his General Syftem of Chemiftry. SPONTANEOUS INFLAMMATION.

On occafion of a frigate that in 1781 took fire in the port of Cronftadt, juft as fhe was preparing to fet fail, though no fire had been made in her for five days before, M. Georgi, of the imperial academy of Peterfburgh, made a great number of experiments. He impregnated gradually three pounds of Pruffian lamp-black with five pounds of boiled hemp feed oil; and after having left the mixture expofed to the air for about five hours, wrapped it up in a coarfe linen cloth. This mafs, after having lain in a cheft for about fixteen hours, yielded a very offenfive and feemingly putrid fmell, not much unlike that of burning oil. Some parts of the mafs grew warm, then hot, and emitted a confiderable quantity of vapour. Thefe vapours were watery, and by no means inflammable. Within about eighteen hours after the packet was made, fome part of it, growing warm, exhibited fmoke, and immediately afterwards was actually ignited. The fame happened at two or three other places, but others were fcarcely warm. The fire fpread very flowly, and emitted a thick ftinking fmoke. M. Georgi then taking the mafs out of the cheft, and laying it on a ftone floor, where it was more expofed Narrative.

* As the Journal de Phyfique is in more hands in this country than the German Annals of Crell, the reader is informed that the whole of the paper of M. Georgi is to be found, in French, in that Journal for July 1782.

SPONTANEOUS INFLAMMATION.

Narrative.

to the air, a flame of about fix inches high arofe, with much fmoke; whenever any openings or crevices were made in the mafs, they threw out vapours, which foon after took fire. The mafs being thrown upon the floor broke in pieces, and a brifk flame arofe on a fudden, about three feet in height, which foon ceafed; when the materials continued to glimmer at firft with fmoke, and afterwards without, for the fpace of fix hours. The whole was confumed in about eight hours. The afhes, which were grey, weighed when cold eight ounces and a half.

In another experiment, exactly fimilar to this as to what relates to the mixture and quantity of the materials, the inflammation did not take place for forty-one hours after the oil had been imbibed by the lamp-black. In general, the inflammation took place much fooner in fine clear days than in rainy weather.

In another experiment he impregnated three pounds of Ruffian lamp-black with three pounds of hemp-feed oil unboiled, and the inflammation took place in the fpace of nine hours.—Twelve ounces of fine German lamp-black, mixed with twenty-four ounces of boiled hemp-feed oil, did not grow warm till after feventy hours were elapfed. It then became gradually hotter, and emitted vapours, which were not inflammable. The re-action of the materials lafted about thirty-fix hours, in which time the heat was fometimes greater, and fometimes lefs, till at laft it ceafed entirely. He made a great many more experiments for the board of admiralty at Peterfburgh, of which the following are the refults. The inflammation takes place much fooner when Ruffian lamp-black, which is coarfe, greafy,

greafy, and heavy, is impregnated with the oil, than when the German lamp-black, which is light and fine, or common wood foot, is employed for this purpofe. With regard to the oils, the inflammation only happens with drying oils, either boiled or crude. The proportion of the lamp-black to the oil differed greatly in thefe experiments: the lamp-black, or foot, took fire with $\frac{1}{10}$ $\frac{1}{5}$ $\frac{1}{3}$ $\frac{1}{2}$ equal parts, and even with twice the quantity of the oil. In general, the inflammation depended more upon the mode of mixing the ingredients than upon the quantity of them: and alfo, as M. Georgi often obferved, upon the weather; for, in wet weather, the mafs, after growing warm, became cold again. SPONTANEOUS INFLAMMATION.

A packet of hemp, of about thirty pounds weight, was impregnated with a mixture of three pounds of tallow and three pounds of hemp-feed oil, and put into a baker's oven, which was heated to 95° of Fahrenheit. On taking it out of the oven an hour afterwards it was hardly warm. In the fpace of an hour after this it began to fmoke, and in another hour the fpontaneous inflammation took place; when M. Georgi obferved that it began about the furface, and not in the middle, of the mafs. He attributed much to the high wind that blew on that day. The packet burned for the fpace of five hours, with a vifible flame. Spontaneous combuftion of hemp with oil

Subfequent to thefe experiments with hemp and flax, this ingenious philofopher made others with wool. He impregnated twenty pounds of wool with a mixture of two pounds of hemp-feed oil, and one of tallow. After having mixed the wool equally with oil, he put it into a fmall baker's oven, and kept it there —alfo of wool.

SPONTANEOUS INFLAMMATION.

Spontaneous combuftion of wool with oil:

there for the fpace of an hour, after which he took it out, and fewed it up in a mat. The packet cooled by degrees, and remained in that ftate three days, at the expiration of which period the wool was found quite found and entire, and the fat was fo thoroughly imbibed by the wool that it was fcarcely perceptible. On the fame wool he now poured a pound of hempfeed oil, and put it again into a baker's oven, of which the heat was 95° of De Lifle's thermometer. After remaining there an hour, it was tied up in a coarfe linen cloth, and laid on fome wood in the laboratory. A few hours after, the packet grew warm in fome places, and emitted a flight fmoke, which increafed to that degree, that two hours afterwards a fpontaneous inflammation took place. The fire glimmered flowly, but when the window was opened it burned for half an hour with a low flame. In the fpace of forty-four hours it ceafed burning, when there remained two pounds and fix ounces of coal, and two pounds of very fine afhes.

—of other fubftances.

He made a great many experiments befides, in which the fpontaneous inflammation took place; fuch as fteeping cow hair and wool in oil, and then expofing them to a certain degree of heat, &c. from which may be drawn this general conclufion, viz. that oils, mixed either with vegetable or with animal fubftances, after they have parted with all their water, begin to take fire. The heat may either have been occafioned by an inteftine motion, as is the cafe when oils are mixed with coarfe lamp-black, or with black wad, where, by the internal heat, the whole of the fluid previoufly evaporates; the inflammation not taking place

place till the water is evaporated: or elfe when vegetable or animal fubftances are impregnated with oils, when the oil, in confequence of the great furface given it, parts with its water fo much the fooner, and thus acquires a folid and fubftantial body with which it can take fire. This inflammation takes place, as Meffrs. Hagemann and Geller have obferved in Crell's Chemical Annals, 1784, p. 488, in the apothecaries' fhops, in oils that are boiled till they are deprived of all their water. SPONTANEOUS INFLAMMATION.

M. Georgi alfo roafted barley, groats, and rice; and he found, that the larger the grains are, the lefs they are difpofed to take fire. Thus coffee roafted brown, and bound up in linen, diid not kindle; the contrary to which however was the cafe with ground coffee, which took fire in three quarters of an hour, and continued fpreading till half an ounce of afhes remained out of two pounds of coffee. In order to fatisfy himfelf that it was only the fize of the coffee berries that prevented the mutual action of the component parts, the abovementioned coffee was ground, and roafted again tolerably brown, and wrapped up in linen. In an hour after this the powder took fire. Spontaneous inflammation of roafted grain:

Saw-duft of mahogany wood was roafted over a gentle fire till it was of a brownifh hue, and kindled in a quarter of an hour after it had been wrapped up. Two pounds of faw-duft of fir wood, on account of the different fize of the particles, became partly black in roafting, and partly white. After being wrapped up, it foon loft its heat, but an hour after the heat returned with fmoke, when quickly it took fire. —of roafted faw-duft.

SPONTANEOUS INFLAMMATION.

In order to know whether the compreffion of vegetable fubftances, and the modification of the air by furrounding them with linen, were effential to the fpontaneous inflammation, and whether a fpontaneous inflammation would take place without the obfervance of this circumftance, M. Georgi roafted fome barley coffee till it was brown, which he put into a fhallow pot, without covering the latter entirely with its lid. After fourteen hours were elapfed, the warmth of the pot returned, and a fmoke arofe. There was no fire perceived in the dark; the infide of the pot however had a phofphoric appearance, and paper and bits of wood foon took fire; and a knife, upon being plunged into the mafs, became red-hot. In twenty-four hours the fire was extinguifhed.

Spontaneous inflammation of malt.

The following remark of M. Georgi is of the greateft importance. In the drying of malt, and in the roafting of other fubftances of a fimilar nature, the malt or other materials may take fire of themfelves in a corner of the kiln a long time after the operation is finifhed, and that even in the open air; and, without giving any figns of accenfion except a trifling degree of fmoke, burn for a confiderable time, and do a great deal of mifchief. From all that has been mentioned it appears, that the fmaller kinds of grain, as well as flour, faw-duft, and other minutely divided and inflammable fubftances, when taken in confiderable quantities, and united with oily matters, are capable of taking fire of themfelves, under certain circumftances, in confequence of their being furcharged with inflammable particles, as well as of an inteftine motion and mutual actions in their conftituent parts, by by which the inflammable particles are difengaged. This is certainly a very remarkable, and hitherto not fufficiently inveftigated, property of many fubftances appertaining to the vegetable and animal kingdoms, the knowledge of which is very important for the farmer, manufacturer, and artift.

SPONTANEOUS INFLAMMATION.

Mr. Lowitz and after him other chemifts have obferved a remarkable property in charcoal, by which it purifies various mucilaginous, faline, and other bodies *. The procefs confifts in adding very pure charcoal, in fine powder, to the folution of the falt. The quantity required is in genral confiderable; and the faline matter is afterwards feparated by the ufual methods of chemiftry, namely filtration, decantation, evaporation, or diftillation, feverally or jointly, as the nature of the fubject may require. It has not been fhewn in what manner the charcoal operates, whether by fimply abforbing the mucilage, or by any procefs of the nature of combuftion. If the latter fhould be probable, our attention fhould perhaps be directed to the air abforbed by the charcoal during its cooling from its firft ignition.

Purification of falts by charcoal.

* The papers of Mr. Lowitz are inferted in Crell's Journal, of which we have two volumes tranflated in Englifh. A confiderable portion of their contents is inferted in the Chemical Dictionary, art. Vinegar and Charcoal, in the Appendix.

CHAP.

CHAP. VII.

CONCERNING FERMENTATION IN GENERAL.

FERMENTATION.

The spontaneous decomposition of vegetables.

THE word Fermentation, in an enlarged sense, is used to denote that change of the principles of organic bodies, which begins to take place spontaneously as soon as their vital functions have ceased, and by which they are at length reduced to their first principles.

Three stages of fermentation:

This has been distinguished into three stages; the vinous or spirituous, the acid or acetous, and the putrid fermentation: which are so called from the principal products obtained during their action. All organized bodies are not subject to the three degrees of fermentation. It is ascertained almost beyond a

—vinous:

doubt that the vinous fermentation takes place only in such bodies as contain saccharine juices. In this the most remarkable product is a volatile, colourless, light, inflammable fluid, which mixes with water in all proportions, and is called ardent spirit. The

—acetous:

acetous fermentation is distinguished by the product known by the name of vinegar, which is the least destructible of the vegetable acids. It does not appear, however, that fermentation is absolutely necessary for

Page 459.

the production of this acid, as there are other chemical means by which it may be obtained, or produced. In

—putrid.

the putrid fermentation, bodies appear to be reduced into their most simple parts. Volatile alkali is the

product

FERMENTATION.

Stages of fermentation.

product which has been remarked as the chief in this procefs, and is no doubt produced by the combination of inflammable and phlogifticated air, which fly off together. The acetous, like the vinous fermentation, is confined to vegetable fubftances; but the putrefactive procefs is moft eminently perceived in animal bodies. Thefe either putrefy immediately; or, if the putrefaction be preceded by either of the other ftages, their duration is too fhort to be perceived. It is confidered as an eftablifhed fact, that the three ftages of fermentation always follow in the fame order, in fuch bodies as are fufceptible of them all; the vinous coming firft, which is followed by the acetous and the putrefactive proceffes.

Conditions or circumftances requifite to the progrefs of fermentation.

The fpontaneous decompofition of bodies is greatly retarded by extreme cold, by fudden drying of the parts, or by prefervation in clofed veffels. The two firft circumftances neceffarily retard the chemical effects, by depriving the parts of that fluidity which is almoft indifpenfably neceffary in chemical proceffes. It will eafily be underftood that the third circumftance will retard the fpontaneous decompofition of bodies, when it is confidered that the atmofphere itfelf is the folvent and receptacle of many of the component parts of bodies with which it is difpofed to combine. In well-clofed veffels, the parts of organized bodies which are difpofed to fly off in the elaftic ftate, are prevented from efcaping; and fuch parts as might form new combinations, by abforbing either the contents or component parts of the atmofphere, are prevented for want of a free communication. The three conditions for the accomplifhment of fermentation are,

 therefore,

FERMENTATION.

therefore, fluidity or moiſture, moderate heat or a due temperature, and the acceſs of air: and the fermentation will likewiſe be modified according to the various component parts of bodies.

Vinous fermentation deſcribed, as it takes place in ſugar and water.

In deſcribing the vinous decompoſition of vegetables, it will be of advantage to attend to that of mere ſugar and water; the phenomena in theſe being more diſtinct, becauſe leſs modified by foreign admixture. If a conſiderable quantity of water, holding in ſolution about one third of its weight of ſugar, be expoſed to the air at the temperature of about 70 degrees, after the addition of a ſmall quantity of yeaſt, it ſoon undergoes a remarkable change. In the courſe of a few hours the fluid becomes turbid and frothy; bubbles of fixed air are diſengaged, which riſe and break at the ſurface. The diſengagement becomes more and more abundant; mucilage is ſeparated, part of which ſubſides to the bottom; and part, expanded into froth by the elaſtic fluid, forms yeaſt. During the courſe of ſeveral days, theſe effects gradually come to their height, and diminiſh again; after which they proceed very ſlowly, but are long before they entirely ceaſe. The fermented liquor has no longer the ſweet taſte it had before, but becomes briſk and lively, with a pungent ſpirituous flavour. Its ſpecific gravity likewiſe is conſiderably leſs than before; and, when expoſed to diſtillation, it affords a light inflammable ſpirit. The quantity of ardent ſpirit which any fermented liquor will produce, is thought to follow ſome proportion of the change its ſpecific gravity undergoes in fermentation; but the truth of this has not been clearly aſcer-

Yeaſt.

Inflammable ſpirit.

afcertained *. Wine, cyder, and beer, are well-known liquors of this kind.

Acetous fermentation.

It is ufual to put fermented liquors into cafks before the vinous fermentation is completely ended; and in thefe clofed veffels it goes on for many months. But if the fermentative procefs be fuffered to proceed in open veffels, more efpecially if the temperature be raifed to 90 degrees, the acetous fermentation comes on. In this the vital part of the air is gradually abforbed; and the more fpeedily, in proportion as the furfaces of the liquor are oftener changed by lading it from one veffel to another. The ufual method confifts in expofing the fermented liquor to the air in cafks, placed fo that the fun may fhine on them; which feems to be of advantage, by raifing the temperature of the liquor. By this abforption of vital air, the inflammable fubftance becomes converted into an acid. If the liquid be then expofed to diftillation, pure vinegar comes over, inftead of ardent fpirit.

Putrefaction.

When the fpontaneous decompofition is fuffered to proceed beyond the acetous procefs, the vinegar gradually becomes vifcid and foul; air is emitted, with an offenfive fmell; volàtile alkali flies off; an earthy fediment is depofited; and the remaining liquid, if any, is mere water. This is the putrefactive procefs.

Though fermentation is much better underftood at prefent, in confequence of modern refearches into the nature of elaftic fluids, than it formerly was, it ftill

* Richardfon on Brewing.

FERMENTATION.

The effect of yeaſt in fermentation.

remains an intereſting object of reſearch. It is not clearly aſcertained what the yeaſt or fermented matter performs in this operation. It ſeems probable that the fermentative proceſs, in conſiderable maſſes, would be carried on in ſucceſſion, from the ſurface downwards; and would perhaps be completed in one part of the fluid before it was perfectly begun in another part, if the yeaſt, which is already in a ſtate of fermentation, did not occaſion the proceſs to begin in every part of the fluid at once. Much remains to be done towards aſcertaining the arrangement and quantity of the component parts of ardent ſpirit: and the theory of fixed air, with the identity of inflammable airs, muſt be aſcertained, before any decided reaſoning can be adopted on this head. It ſeems however that inflammable air, in combination with fixed air in certain proportions, forms ardent ſpirit; that a greater proportion of vital air converts it into vinegar; and that, in the putrefactive proceſs, the inflammable air, the fixed air, and the vital air, are ſeparated from each other, and fly off in the elaſtic ſtate.

Component parts of ardent ſpirit, &c.

Tartar.

In the fermentation of wine, the tartar, which probably exiſted for the moſt part ready formed in the juice of the grape, is ſeparated, and exhibits the properties which have been already deſcribed in treating of that ſubſtance.

Bread.

The fermentation of bread by leaven is thought to be of a different nature from the vinous fermentation. In this the mucilage of the corn is not previouſly brought into the ſaccharine ſtate. It quickly becomes ſour, if the proceſs be not ſtopped by baking; in which particular, the fermentation ſeems to be of the

FERMENTATION. Bread.

the acetous kind. The development of fixed air divides the dough into thin parts, which are more effectually and better baked than they could have been in the folid confiftent mafs. When bread is fermented by means of yeaft, the procefs appears to be of a faccharine or vinous nature.

CHAP.

CHAP. VIII.

CONCERNING VINOUS FLUIDS AND ARDENT SPIRITS.

VINOUS FLUIDS.

The making of wine from grapes.

FROM the habits of society, the making of wine, beer, and ardent ſpirits, is become an object of conſiderable importance. Wine is the expreſſed juice of the grape which has undergone the firſt ſtage of fermentation. In this, which in general appears to be the beſt kind of fermented liquor, there are great differences, which depend no leſs on the kind and quality of the fruit than on the proceſs of manufacturing. If the fruit be gathered unripe, the juice will abound with acid, and the wine will be thin and ſharp; but, if the fruit be ripe, it will contain much ſaccharine juice, and the wine will be ſweeter. If the wine be caſked in an early ſtage of the fermentation, much of the ſugar will remain undecompoſed, and the wine will be ſweeter on that account, eſpecially if the fermentation be checked by a conſiderable degree of cold; but, on the contrary, when the progreſs of the fermentation is only impeded by the coercion of the veſſel, which prevents the eſcape of the fixed air, a ſlight increaſe of temperature, ſuch as that of a room in a dwelling-houſe compared with the temperature of a cellar, will cauſe it to proceed with great rapidity as ſoon as the veſſel is opened. Wines in this ſtate are very briſk and lively, from the predominating acidity of the fixed air, which is haſtily diſengaged.

Beer

The malting of barley:

Beer is the wine of grain. Malt is ufually made of barley. This grain is fteeped for two or three days in water till it fwells, becomes fomewhat tender, and tinges the water of a bright reddifh brown colour. The water being then drained away, the barley is fpread about two feet thick upon a floor, where it heats fpontaneoufly, and begins to grow, by firft fhooting out the radicle. In this ftate the germination is ftopped, by fpreading it thinner, and frequently turning it over for two days; after which, it is again made into an heap, and fuffered to become fenfibly hot, which ufually happens in little more than a day. Laftly, it is conveyed to the kiln, where, by a gradual and low heat, it is rendered dry and crifp. This is malt; and its qualities differ according as it is more or lefs foaked, drained, germinated, dried, and baked. In this, as in other manufactories, the intelligent operators often make a myftery of their proceffes, from views of profit; and others pretend to peculiar fecrets, who really poffefs none.

—of Indian corn.

Indian corn, and probably all large grain, require to be fuffered to grow into the blade, as well as root, before it is fit to be made into malt. For this purpofe, it is buried about two or three inches deep in the ground, and covered with loofe earth; and in ten or twelve days it fprings up. In this ftate it is taken up and wafhed, or fanned, to clear it from its dirt, and then dried in the kiln for ufe.

Brewing of beer.

Beer is made from malt previoufly ground, or cut in pieces by a mill. This is placed in a tun, or tub, with a falfe bottom; hot water is poured upon it, and the whole ftirred about with a proper inftrument. The

 tempe-

VINOUS FLUIDS.

Brewing of beer.

temperature of the water in this operation, called maſhing, muſt not be equal to boiling; for in that caſe the malt would be converted into a paſte, from which the impregnated water could not be ſeparated. After the infuſion has remained for ſome time upon the malt, it is drawn off, and is then diſtinguiſhed by the name of ſweet wort. By one or more ſubſequent infuſions of water, a quantity of weaker wort is obtained, which is either added to the foregoing, or kept apart, according to the intention of the operator. The wort is then boiled with hops, which give it an aromatic bitter taſte, and are ſuppoſed to render it leſs liable to be ſpoiled in keeping; after which, it is cooled in ſhallow veſſels, and ſuffered to ferment, with the addition of a proper quantity of yeaſt. The fermented liquor is beer; and differs greatly in its quality, according to the nature of the grain, the malting, the maſhing, the quantity and kind of the hops and the yeaſt, the purity or admixtures of the water made uſe of, the temperature and viciſſitudes of the weather, &c.

Metheglin and koumiſs.

Beſides wine and beer, which are made immediately from vegetables; other fermented liquors, containing ardent ſpirit, are made from honey and from mare's milk. The former is called metheglin; and the latter, which is made by the Tartars, koumiſs *. This laſt is made by agitating the milk, at the time when its parts begin to ſeparate, by a fermentation productive of a peculiar acid, called the acid of milk, hereafter to be deſcribed.

* Grieve, in the Edinburgh Tranſactions, vol. i. p. 181.

In

ARDENT SPIRIT.

In order to obtain ardent ſpirit, nothing more is neceſſary than to expoſe wine, beer, or any other fermented vinous liquid, to diſtillation; and the product which comes over is the ardent ſpirit itſelf, contaminated with eſſential oil. If this be rectified by a ſecond diſtillation, it becomes much purer. The moſt volatile part riſes firſt, and is of a leſs ſpecific gravity than that which comes over afterwards. Product of vinous liquors by diſtillation.

The reſidue, after the diſtillation of ardent ſpirit from wine, is of a deep colour, a rough acid taſte, and depoſits cryſtals of tartar. The colouring matter is ſoluble in ardent ſpirit. So that it appears, from this imperfect analyſis, that wine conſiſts of water, ardent ſpirit, colouring matter of a reſinous nature, ſugar, tartar, and tartareous acid, and an aromatic principle. Reſidue.

The ſtrength or purity of ardent ſpirit is aſcertained from its ſpecific gravity; for the addition of water renders it heavier. According to M. Bories, whoſe Memoir, publiſhed at Montpellier in the year 1774, obtained the prize propoſed by the ſtates of Languedoc in 1772, the ſpecific gravity of rectified ardent ſpirit, repeatedly poured on dry ſalt of tartar till it would no longer diſſolve or liquefy it, was found by many experiments to be as follows: Strength of ardent ſpirit determined by M. Bories.

Reaumur's Therm. $+ 10° = 820 \frac{2000}{5055}$

$15° = 817 \frac{65}{5055}$

$20° = 813 \frac{2284}{5055}$

The ſpecific gravities of mixtures, by meaſure, of the foregoing ſpirit with diſtilled water, were as follows:

 Tempe-

ARDENT SPIRIT.

Specific gravities of various mixtures of water and spirit.

Temperature + 15° Reaumur.

Spirit	Water	Specific gravity
10	0	$817 \frac{65}{5055}$
9	1	$844 \frac{3590}{5055}$
8	2	$869 \frac{4705}{5055}$
7	3	$893 \frac{1805}{5055}$
6	4	$915 \frac{925}{5055}$
5	5	$934 \frac{3630}{5055}$
4	6	$951 \frac{3695}{5055}$
3	7	$965 \frac{1925}{5055}$
2	8	$976 \frac{1320}{5055}$
1	9	$987 \frac{715}{5055}$
0	10	1,000

Obfervations.

Upon the above experiments, which are among the moft accurate we poffefs*, it may be obferved, that the firft term, or pure fpirit, ought to be obtained with an alkali perfectly mild, or faturated with fixed air; becaufe, otherwife, folution and combination of the alkali with the fpirit might take place. By diftillation of twenty meafures of the beft ardent fpirit of the fhops, whofe fpecific gravity was 0.836 over a lamp in glafs veffels, I found the firft meafure which came over had a fpecific gravity of 820, at the temperature of 71° Fahrenheit; which anfwers to $17\frac{1}{3}$ of Reaumur. This is the ftrongeft fpirit mere diftillation can afford. When ftrong ardent fpirit is added to water, a confiderable heat is produced, a few bubbles of air are emitted, the mixture contracts in its dimenfions, and acquires a greater fpecific gravity than would have been deduced by computation.

Strongeft ardent fpirit by mere diftillation.

* See a very valuable fet of experiments on this fubject by Mr. Gilpin; of which Dr. Blagden has made a report in the Phil. Tranf. lxxx. 321. Thefe are amply tabulated in the Tranfactions for 1794, and an abftract of the refults is given in the Chemical Dictionary, Art. *Spirit, ardent.*

It

ARDENT SPIRIT.

Requisites or desiderata to ascertain the strength of spirit.

It is by no means an easy undertaking to determine the strength or relative value of ardent spirit, even with sufficient accuracy for commercial purposes.—The following requisites must be obtained before this can be well done: The specific gravity of a certain number of mixtures of ardent spirit and water must be taken so near each other, as that the intermediate specific gravities may not perceptibly differ from those deduced from the supposition of a mere mixture of the fluids: the expansions, or variations of specific gravity, in these mixtures, must be determined at different temperatures: some easy method must be contrived of determining the presence and quantity of saccharine or oleaginous matter which the spirit may hold in solution, and the effect of such solution on the specific gravity: and, lastly, the specific gravity of the fluid must be ascertained by a proper floating instrument with a graduated stem, or set of weights; or, which may be more convenient, with both.

Phial proof.

The strength of brandies in commerce is judged by the phial, or by burning. The phial proof consists in agitating the spirit in a bottle, and observing the form and magnitude of the bubbles, which are larger the stronger the spirit. These probably depend on the solution of resinous matter from the cask, which is taken up in greater quantities, the stronger the spirit. It is not difficult however to produce this appearance, by various simple additions to weak spirit.—The proof by burning is also fallacious; because the magnitude of the flame, and quantity of residue, in the same spirit, vary greatly with the form of the vessel it is burned in. If the vessel be kept cool, or suffered to become hot,

Proof by burning.

ARDENT SPIRIT.

if it be deeper or ſhallower, the reſults will not be the ſame in each caſe. It does not follow, however, but that manufacturers and others may in many inſtances receive conſiderable information from theſe ſigns, in circumſtances exactly alike, and in the courſe of operations wherein it would be inconvenient to recur continually to experiments of ſpecific gravity.

Characters and component parts of ardent ſpirit:

The moſt remarkable characteriſtic property of ardent ſpirit is its ſolubility or combination in all proportions with water; a property poſſeſſed by no other combuſtible ſubſtance. When it is burned in a chimney which communicates with the worm-pipe of a diſtilling apparatus, the product which is condenſed is found to conſiſt of water, which exceeds the ſpirit in weight about one eighth part. If ardent ſpirit be burned in cloſed veſſels with vital air, the product is found to be water and fixed air. Whence it is inferred, that ardent ſpirit conſiſts of inflammable air, united either to fixed air, or its acidifiable baſe; and that the vital air, uniting on the one part with inflammable air, forms water; and, on the other, with the baſe of the fixed air, and forms that acid*.

—its uſes and combinations.

A conſiderable number of the uſes of this fluid, as a menſtruum, have already paſſed under our obſervation. The mutual action between ardent ſpirit and acids, produces a light, volatile and inflammable oil, called ether. Pure alkalis unite with ſpirit of wine, and form alkaline tinctures. Few of the neutral ſalts unite with

* For an account of theſe experiments, and the precautions neceſſary to be attended to in making them, conſult the Memoirs of M. Lavoiſier, in the Memoirs of the Royal Academy at Paris for 1781 and 1784.

this

ARDENT SPIRIT.

this fluid, except ſuch as contain the volatile alkali. The mild fixed alkalis, or combinations of alkali and fixed air, are not ſoluble in it. From the ſtrong attraction which exiſts between ardent ſpirit and water, it unites with the laſt in ſaline ſolutions, and in moſt caſes precipitates this ſalt. This is a pleaſing experiment, which never fails to ſurpriſe thoſe who are unacquainted with chemical effects. If, for example, a ſaturated ſolution of nitre in water be taken, and an equal quantity of ſtrong ſpirit of wine be poured upon it, the mixture will conſtitute a weaker ſpirit, which is incapable of holding the nitre in ſolution; it therefore falls to the bottom inſtantly, in the form of minute cryſtals. Among the neutral ſalts which are ſoluble in ſpirit of wine, the deliqueſcent earthy ſalts ſtand firſt. Moſt ammoniacal ſalts are ſoluble in this menſtruum; and in general it combines more readily with ſuch as have their acid leſs adherent to the neutralizing baſe.

Mutual action of ardent ſpirit and ſalts:

Sulphur does not appear to be acted on more ſtrongly by ardent ſpirit than by water. If ſulphur in ſublimation meet with the vapour of ſpirit of wine, a very ſmall portion combines with it, which communicates an hepatic odour to the fluid. The increaſed ſurface of the two ſubſtances appears to favour the combination.

—and ſulphur:

Phoſphorus is ſparingly ſoluble in ardent ſpirit, but in greater quantity by heat than in the cold. The addition of water to this ſolution affords an opake milky fluid which gradually becomes clear by the ſubſidence of the phoſphorus.

—and phoſphorus.

Earths ſeem to have ſcarce any action upon ardent ſpirit.

—and earths.

ARDENT SPIRIT.

ſpirit. Quick-lime however produces ſome alteration in this fluid, by changing its flavour, and rendering it of a yellow colour. A ſmall portion is probably taken up.

Spirituous ſolutions.

Soaps are diſſolved with great facility in ardent ſpirit, with which they combine more readily than with water. None of the metals, nor their calces, are acted upon by this fluid. Reſins, eſſential oils, camphor, bitumen, and various other ſubſtances, are diſſolved with great facility in ardent ſpirit, from which they may be precipitated by the addition of water.

CHAP. IX.

CONCERNING THOSE INFLAMMABLE FLUIDS WHICH ARE PRODUCED BY THE ACTION OF ACIDS UPON SPIRIT OF WINE, AND ARE KNOWN BY THE NAME OF ETHER.

ETHER. The making of vitriolic ether.

WHEN ftrong vitriolic acid is poured upon an equal meafure of rectified fpirit of wine, the two fluids unite together, with a hiffing noife and the production of heat, at the fame time that a fragrant vegetable fmell is emitted, refembling that of apples. It is more advantageous, however, to add the acid in fo gradual a manner as to produce little or no heat. If the mixture be made in a retort, and then expofed to diftillation by a well-regulated heat in a fand-bath, a large receiver being adapted, and kept cool by immerfion in water, or by the frequent application of wet cloths, the volatile products may be fafely condenfed. Spirit of wine of a fragrant fmell comes over firft, and is followed by the ether, as foon as the fluid in the retort begins to boil. At this period the upper part of the receiver is covered with large diftinct ftreams of the fluid, which run down its fides. After the ether has paffed over, volatile fulphureous acid arifes, which is known by its white fumes and peculiar fmell. The receiver muft now be removed, and another fubftituted in its place, care being taken to avoid breathing the penetrating fumes of the acid. The

ETHER. Distillation of vitriolic ether.

The fire must at the same time be moderated, because the residue in the retort is disposed to swell. A light yellow oil, called sweet oil of wine, comes over after the ether, and this is succeeded by black and foul vitriolic acid. The residue varies in its properties, according to the management of the heat. If the fire be much increased towards the end of the process, the volatile vitriolic acid which comes over will be mixed with vinegar. If the remaining fluid contained in the retort, after the ether has passed over, be not urged farther, it may be made to afford more ether by the addition of one-third of very strong ardent spirit; and this may be repeated successively, until near twice the quantity of the spirit originally made use of has been added.

Rectification.

Ether of the first distillation is not pure, but contains spirit of wine and sulphureous acid, which may be separated by the addition of a fixed alkali, and rectifying with a gentle heat. In this rectification, as in all others, the first products are the purest.

Characters.

Vitriolic ether is one of the lightest and most volatile of all dense and unelastic fluids. Its dissipation into the air is so sudden as to produce an extreme degree of cold. It is highly inflammable, and burns with a more luminous flame, and emits more smoke, than ardent spirit.

Solubility in water.

About ten times its weight of water is sufficient to dissolve it. A small proportion of water renders unrectified ether more pure, because it combines with the ardent spirit and acid it may contain; but there is reason to think, on the other hand, that the ether dissolves, and combines with part of the water.

Little

Combinations of vitriolic ether.

Little is known of the action of this fluid upon faline fubftances. Lime and fixed alkalis do not feem capable of uniting with it. Cauftic volatile alkali combines with it in all proportions; vitriolic acid unites with it, and extricates heat, and from this combination fweet oil of wine may be obtained by diftillation. Nitrous acid effervefces with ether, and renders it more oily. It diffolves camphor very plentifully.

Method of preparing nitrous ether.

The nitrous acid acts very rapidly and powerfully upon ardent fpirit, with which it forms a combination, poffeffing properties fimilar to thofe of the vitriolic ether. The combination takes place without the affiftance of heat, and with fuch facility, that it is even neceffary to add the acid by degrees, and to ufe management for the purpofe of preventing an explofion, which might arife from the heat generated by the mixture. For this purpofe, fix ounces of highly rectified fpirit of wine are put into a bottle capable of containing a pound of water, and immerfed in a tub of very cold water, in which it will be advantageous to put three or four pounds of ice broken fmall. Upon the fpirit in this fituation, and kept continually agitated, four ounces of fpirit of nitre, of the fpecific gravity of 1.5, are to be poured, in four or five fucceffive portions. As foon as the mixture is completed, the bottle muft be clofed with a good cork, fecured with leather and packthread, or wire; and the whole muft be left in a place where it may remain undifturbed; no other attention being neceffary than that of renewing the water, from time to time, as it may become heated. In the courfe of two or three hours, the

ETHER.

Methods of preparing nitrous ether.

the tranfparency of the fluid becomes troubled by an infinity of drops of ether, which are difengaged from every part of its volume. This ether gradually rifes to the furface; and at the end of twenty-four hours it may be feparated from the reft of the liquor by means of a funnel. In opening the phial, it is neceffary firft to pierce the cork with a pointed inftrument, in order that a quantity of elaftic fluid may efcape, which might otherwife fuddenly follow the cork, and carry part of the fluid along with it. The quantity of ether obtained in this manner will be about four ounces.

Characters.

Nitrous ether in this ftate refembles vitriolic ether in its fmell, but it is ftronger and lefs agreeable. Its colour is a light orange; and a portion of the fluid takes the elaftic form, and efcapes with effervefcence whenever the bottle, which contains it, is opened. This ether appears to contain a portion of uncombined acid, upon which thefe phenomena probably depend. It muft be rectified with a fmall addition of alkali, during which operation it lofes near half its weight. The rectified nitrous ether burns with a flame rather more luminous than that of vitriolic ether, at the fame time that it affords a fomewhat larger portion of fmoke, and leaves a black trace behind it. In other refpects it feems nearly to refemble the vitriolic ether.

Nitrous ether may be made with lefs danger, if the acid be diluted, and the quantity of fpirit duly proportioned. It may alfo be had by diftillation of a mixture of the two fluids, in the fame manner as the vitriolic ether; but in this cafe it is requifite that the receiving veffels fhould be uncommonly large, and that

Methods of preparing nitrous ether.

that every precaution should be taken to prevent their flying in pieces by the force of the elastic product which escapes; and, upon the whole, it does not seem probable that any ordinary degree of precaution would be sufficient to insure the operator from danger in this distillation. One very essential circumstance consists in using the acid in a diluted state.—Nitrous ether has also been made by less direct processes. If a due proportion of nitre and vitriolic acid be successively put into a tubulated retort, the nitrous acid begins to be disengaged; and, if spirit of wine be added to this mixture, nitrous ether comes over. Some degree of precaution is necessary in this process; and it might be doubted whether part of the ether which comes over might not have been formed by the vitriolic acid, if most of the difficulties were not removed by the use of the apparatus, fig. 22. If the tube E be immersed in a bottle containing highly rectified spirit of wine, and the nitrous acid be distilled from a quantity of nitre equal in weight to twice the spirit of wine, together with as much concentrated vitriolic acid as is equal to half the weight of the nitre; the first receiver D will, at the end of the operation, contain fuming nitrous acid; the remote bottle E will contain an ethereal liquor; and the residue will be vitriolated tartar. The ethereal spirit of wine may then be distilled, and the first two-thirds of the product reserved. This reserved product must be distilled with one-fifth of its weight of smoking nitrous acid, added by degrees to the liquor in a tubulated retort, by means of a long-necked funnel. Two-thirds of this product only are to be taken; which, being rectified

fied

ETHER. Nitrous ether.

fied from pot-afh, afford at firft a quantity of very pure nitrous ether, equal to about one-twelfth of the fpirit made ufe of; and three-fourths of the reft being diftilled over confift of a lefs perfect ether, or mineral anodyne liquor. The refidues of the diftillations confift of dulcified fpirit of nitre *.

It is proper, even here, to take notice that all mixtures of the nitrous acid and ardent fpirit require to be made very gradually, and with great caution, for fear of explofions.

The refidue, after diftillation of nitrous ether, is found, in fome proportions of the materials and management of the procefs, to contain no nitrous acid, but an imperfect vinegar, and the acid of fugar or forrel.

Method of preparing marine ether.

The marine acid cannot be combined with fpirit of wine in the direct way. There are many indirect methods, which confift in applying the dephlogifticated or aërated marine acid to ardent fpirit. If to four ounces of common falt, and two ounces of pulverized manganefe, there be added two ounces of concentrated vitriolic acid, and fix ounces of the pureft ardent fpirit, and the whole be expofed to diftillation by a gentle heat, the marine acid will firft rife, fomewhat changed; and, after a confiderable portion has paffed over, it muft be poured back upon the refiduum, and diftilled afrefh. In this diftillation, nearly the half which firft comes over will be dulcified fpirit of falt; and the greateft part of the other half, marine ether, which may be feparated from the reft by the addition of water.

* De la Planche, quoted by Fourcroy, iv. 252.

Marine ether is very tranfparent and volatile, and has nearly the fame fmell as the vitriolic ether. It burns like that fluid, and affords a fmoke, with a fuffocating fmell.

Methods of preparing acetous ether.

It is doubted whether any ethereal fluid can be obtained by the direct union of acetous acid and ardent fpirit. If equal parts of the ftrongeft acetous acid and ardent fpirit be mixed together, and kept for fome days in a well-ftopped glafs, and the mixture be then expofed to diftillation by a gentle heat, the firft half which comes over will, it is faid, confift of an ethereal fluid, from which the ether may be feparated by the addition of a fixteenth part of vegetable alkali diffolved in four times its quantity of water. The ether immediately rifes to the top, and commonly amounts to one half of the quantity of the ardent fpirit made ufe of. To the vinegar that remains in the retort half the quantity of ardent fpirit may be added, by which ftill more of the ether may be obtained. The moft certain and incontrovertible method, however, appears to confift in forming the union between the fpirit and acid by indirect means. This may be done by decompofing fome acetous falt, by the addition of a mineral acid, while ardent fpirit is prefent. Thus, if an ounce of alkali faturated with vinegar be diffolved in three ounces of fpirit of wine, and a little more of any mineral acid than is fufficient to faturate the alkali be added, and the mafs be then diftilled, acetous ether will be obtained. Or if eight ounces of fugar of lead be gently dried, to deprive it of its water of cryftallization, which amounts to rather more than one-fourth of its weight; if in this ftate it be put

ETHER. Acetous ether.

put into a glafs retort, and a mixture of five ounces of vitriolic acid, and eight ounces of fpirit of wine, be poured on it, and the whole expofed to diftillation by a very gentle heat, the firft ounce that paffes over will confift of dulcified acetous acid, the next ounce will be almoft all ether, and the whole quantity of ether produced will be near four ounces.

Acetous ether is not nearly fo volatile as the nitrous or vitriolic; it burns with a blue flame, like fpirit of wine.

Ligneous ether.

The empyreumatic acid of wood likewife affords an ether. For this purpofe it may be diftilled from beech, rectified a fecond time, and then faturated with alkali. Three pounds of the acid require about five ounces of alkaline falt. By evaporation to drynefs, with fubfequent folution, filtration, and evaporation, three ounces and a quarter of neutral falt are obtained. The concentrated acid of wood may be difengaged from this by diftillation with two ounces of vitriolic acid; and the quantity of acid of wood thus obtained weighs an ounce and three quarters. By mixing this with an equal quantity of pure ardent fpirit, and diftilling it in a fmall retort, near two ounces and a quarter of ether are obtained.

Saccharine ether.

Equal parts of falt of forrel and ardent fpirit afford about one-fifth of their weight of ether. The acid of fugar likewife affords an ether with fpirit of wine, which can hardly be fuppofed to differ from the foregoing, as the two falts are the fame.

Phofphoric ether.

The acid of phofphorus does not produce an ethereal combination by direct diftillation with ardent fpirit: but it is faid that the combination takes place with

with a due mixture of ardent ſpirit, vitriolic acid, and microcoſmic ſalt; the phoſphoric acid being expelled from its baſe, probably in a more dephlogiſticated ſtate than when obtained by ſuffering phoſphorus to deliqueſce in the air.

Ether produced by acid of ants:

The acid of ants produces an ether, with ſpirit of wine, by ſimilar treatment.

—by acid of benzoin.

Acid of benzoin does not produce ether by ſimple ſolution, and ſtanding in ſpirit of wine; but, when one part of the acid of benzoin is diſtilled with three parts of ardent ſpirit, and one half part of common marine acid, the pure ſpirit comes firſt over, and afterwards an ethereal combination, one part of which floats upon water, and the other ſinks to the bottom. This is not more volatile than acetous ether, and burns with a bright flame and ſmoke.

General obſervations.

The converſion of ardent ſpirit into ether, is a proceſs concerning which much remains to be explained. It was formerly thought that the acid did nothing more than deprive the ſpirit of a quantity of water, which was before combined with it, and prevented its exhibiting oleaginous properties. It ſeems aſcertained however, at preſent, that all the ethers contain a portion of that peculiar acid by whoſe action the ſpirit was changed; as may be ſhewn by ſuffering them to evaporate, or burning them away upon water. It appears therefore that the acid, or ſome of its component parts, combine either with the whole or part of the ardent ſpirit. Some chemiſts have with conſiderable probability aſſerted, that the baſis, or acidifiable principle, of the acid combines with the ſpirit by the effect of a double affinity; ſo

 that

ETHER. Theoretical obfervations.

that the vital air of the acid combines with a portion of acetous bafis exifting in the fpirit, and forms vinegar; another portion combines with the vegetable principles exifting in fuch a ftate as to form the faccharine acid; and, laftly, the acidifiable bafis itfelf, which gave out this vital air, is fuppofed to combine with the undecompofed fpirit, or vegetable inflammable matter, and rife in the form of ether. In this view of the fubject, the nitrous ether is more particularly attended to, and the inferences are extended to other ethers; and oils are fuppofed to confift of vegetable inflammable matter, combined with the bafis of an acid *.

* On Ethers, fee Wiegleb's Chemiftry, by Hopfon, p. 510 et feq; Scheele's Effays, &c.

CHAP.

CHAP. X.

CONCERNING THE ACETOUS ACID.

ACETOUS ACID.

AS moſt of the compounded vegetable acids are convertible, by nitrous acid and by other means, into acid of ſugar, and this laſt into vinegar, it is evident that fermentation is only one of the proceſſes which change the principles of plants into this leaſt deſtructible of vegetable acids. All the vinegar however which is uſed in the common purpoſes of life, is obtained by fermentation. Crude vinegar contains not only that peculiar acid which is diſtinguiſhed by the name of acetous, but likewiſe tartar, oily matter, and frequently ſome of the acids of the fruits from which it may have been procured. It is uſual to purify it by diſtillation. The firſt product conſiſts of a watery fluid, of a lively and agreeable ſmell, though ſcarcely acid. Next follows the acetous acid, commonly called diſtilled vinegar, which has a peculiar ſmell, leſs agreeable than that of the crude vinegar. As the diſtillation proceeds, the volatile product becomes more and more acid, ſomewhat darker coloured, and of an empyreumatic ſmell. The reſidue, after the greateſt part of the fluid has been volatilized, has a deep browniſh red colour, is conſiderably acid, and depoſits a quantity of tartar. By diſtillation to dryneſs, it affords a reddiſh phlegm; more acid; an oil, at firſt light, and afterwards heavy; together with a ſmall quantity of volatile alkali: the reſidual coal con-

Crude vinegar.

Diſtilled vinegar, or acetous acid.

ACETOUS ACID.

tains much fixed alkali. The quantity of acid product reſerved as diſtilled vinegar, is commonly about two-thirds of the whole.

Concentration of vinegar by froſt.

Vinegar may be concentrated by froſt, which ſeparates its aqueous part. This proceſs is particularly applicable to crude vinegar; as, by this means, the grateful flavour and peculiar properties are preſerved. An ingenious method has been contrived for combining the two proceſſes of diſtillation and congelation, in concentrating and purifying vinegar. In this way, good wine vinegar is to be diſtilled on a water bath. It is eſſential to reſerve the phlegm, becauſe the moſt fragrant parts come over firſt, and are retained in this fluid. The diſtilled vinegar and phlegm being then expoſed to a freezing cold, and the ice taken out, a concentrated acid remains; which may be completely deprived of its extraneous and oily parts by repeated rectifications on a water bath. At the beginning of the rectification, a very ſpirituous fluid paſſes over; which being ſeparated, and rectified by itſelf, yields a true and fine ether, of a very pleaſant ſmell, and immiſcible with water; which ether is to be added to the ſtrong and purified vinegar obtained by the repeated rectifications. The author of this method obſerves, that the peculiar and unpleaſant ſmell of diſtilled vinegar proceeds from ſome oily parts which paſs over in the diſtillation; and that, when theſe parts have been ſeparated by rectifying the acid concentrated by froſt, it again recovers the pleaſant ſmell of undiſtilled vinegar *.

The moſt advantageous method of concentrating vinegar.

* Lowitz, in Crell's Annals, quoted by Keir in his Chemical Dictionary, page 32.

Pure

ACETOUS ACID.

Combinations of acetous acid:

Pure acetous acid enters into many combinations; and is recovered again by decompoſition, though ſeldom perhaps in its original ſtate. In many of its combinations it ſeems neceſſary that it ſhould become more ſtrongly acidified by attracting vital air from the atmoſphere, or from other bodies. This circumſtance has not been ſufficiently attended to, to admit of a proper diſtinction of every caſe in which it may, or may not, happen. We ſhall not therefore attempt to point them out, except incidentally, and where the facts are clear.

—with argillaceous earth:

The acetous acid unites with earth of alum, or argillaceous earth, in conſiderable quantity, and forms a whitiſh ſaline maſs, which is not cryſtallizable. There is however a diſagreement among practical chemiſts reſpecting this combination. Some aſſert that it takes place very ſparingly, and forms ſmall needled cryſtals. Theſe differences may probably depend on certain circumſtances relative to the edulcoration of the earth of alum, after it has been precipitated from its ſolution by an alkali.

—with calcareous earth:

Calcareous earth is readily diſſolved in the acetous acid, and forms a ſalt, the figure of whoſe cryſtals varies according to circumſtances. It is permanent in the air, unleſs the acid be in exceſs; in which caſe it deliqueſces. Its taſte is ſharp and bitter. When diſtilled without addition, the acid quits the earth, and appears in the form of an inflammable vapour, which condenſes into a reddiſh brown liquor; and, when rectified, is very volatile and inflammable.

The acetous acid forms a ſaline maſs by combina-

 tion

ACETOUS ACID.

tion with ponderous earth, which does not cryſtallize, but, if dried, attracts moiſture from the air.

Combination of acetous acid with magneſia: Magneſian earth unites with acetous acid, and affords a very ſoluble ſalt; which, when perfectly ſaturated and evaporated, affords a viſcid maſs, reſembling gum water. Its taſte is ſweetiſh at firſt, but afterwards bitter; and it is ſoluble in ſpirit of wine. Mere heat diſſipates its acid, which may be obtained by diſtillation.

—with vegetable alkali. Foliated earth of tartar. The combination of vegetable alkali with the acetous acid, produces the ſalt improperly called foliated earth of tartar. In the preparation of this ſalt, it is beſt to add an exceſs of acid. The evaporation muſt be carried to dryneſs on a water bath, in a glaſs or ſilver veſſel. This ſalt cannot eaſily be cryſtallized. Its taſte is penetrating, acrid, and urinous; heat decompoſes it: by diſtillation, it affords an acid phlegm, empyreumatic oil, volatile alkali, and much elaſtic fluid, conſiſting of fixed and inflammable air. The reſidual coal contains much vegetable alkali. If foliated tartar be decompoſed by the addition of vitriolic acid in diſtillation, the quantities being one part of the concentrated acid to two of the ſalt, in a tubulated retort, with a receiver, or apparatus of veſſels adapted, the acetous acid immediately riſes in the elaſtic form, with a ſtrong effervescence, and is condenſed in the receiver. This fluid is called radical vinegar, and its acid properties are more intenſe than thoſe of common acetous acid. It is highly probable that this augmentation of acidity is produced by the tranſition of vital air from the vitriolic acid to the acetous; perhaps with the contrary tranſition of phlogiſton.

Radical vinegar.

ACETOUS ACID.

gifton. So that, while the acetous acid becomes more acidified, a portion of the vitriolic acid has its acidity diminifhed, and is converted into fulphureous acid, which comes over, and contaminates the product in the receiver.

Combinations of acetous acid:

—with mineral alkali:

The acetous acid unites perfectly with the mineral alkali, and forms a cryftallizable permanent falt. The properties of the acetous falt of mineral alkali do not remarkably differ from thofe of the foliated earth of tartar. By diftillation with vitriolic acid, it affords a purer acetous acid than the foliated tartar does.

—with volatile alkali:

The falt formed by uniting acetous acid with volatile alkali, has been called fpirit of Mindererus, or acetous fal ammoniac. It does not eafily cryftallize; for which purpofe it requires to be evaporated to the confiftence of fyrup, and then expofed to the cold. It foon attracts the moifture of the air, and has a fharp and burning tafte. This falt is decompofable by heat; by lime and alkalis, which feize its acid; or by the mineral acids, which feize its bafe.

—with gold:

The acetous acid has no effect on gold in the metallic ftate. When added to a folution of gold, it throws it down in the metalline form. The precipitate of gold effected by a fixed alkali becomes of a purple colour when digefted with the common acetous acid. Radical vinegar diffolves it.

—with filver.

Silver is not acted on by acetous acid; though the calces of this metal, obtained by an alkali from nitrous acid, are foluble.

Platina is likewife infoluble in this acid; though its precipitate from aqua regia, by a fixed alkali, is foluble.

ACETOUS ACID.

Combination of acetous acid with mercury: Acetous acid does not appear to be affected by mercury; but it diffolves the mercurial calces. The cryftals of this folution have a foliated appearance, refembling that of the acid of borax.

—with lead: Lead is diffolved with the greateft facility by vinegar. The manufacture of cerufe and fugar of lead has before engaged our attention. Page 279.

—with copper: Copper is likewife foluble in vinegar, provided atmofpheric air be prefent. The cryftals of acetous acid and copper are improperly called diftilled verdigrife. It is from this falt that radical vinegar has ufually been diftilled by mere heat, without addition. It is at firft coloured by a portion of copper, which comes over; for which reafon it muft be rectified by a gentle heat. The refidue, after diftilling the acetous falt of copper, confifts of the metal in its reguline ftate; whence it is feen that the vital air required to calcine the copper, comes over with the acid, which confequently is in a dephlogifticated or aërated ftate. The laft portion of radical acid which comes over is inflammable, and congealable by cold.

—with iron. Iron is readily diffolved by the acetous acid, with a flight effervefcence, and the difengagement of inflammable air. This folution depofits much calx of iron by evaporation; and yields a few deliquefcent cryftals when cool. Very little action takes place between common vinegar and iron filings, unlefs by ftanding; during which time, it is probable that the action of the air may contribute in fome degree to the effect. Compare page 318.

—with tin. When tin is digefted with the acetous acid, a fmall portion appears to be taken up. The acid becomes turbid,

turbid, acquires a metallic tafte, and affords a fmall quantity of precipitate by alkalis.

ACETOUS ACID.

Metallic combinations.

Bifmuth and its calx are foluble in this acid, though fparingly. Nickel is diffolved, and the folution affords green cryftals. Regulus of arfenic is infoluble, but its calx is taken up. The regulus of cobalt is likewife infoluble; its calx affords a pale rofe-coloured folution, which is a fympathetic ink, and receives a green colour from marine acid. Zinc is foluble not only in its metallic and calciform ftates, but alfo, as it is faid, when mixed with other metals: hence it fhould feem ill calculated to defend copper veffels from the action of this vegetable acid. The folution of zinc in common acetous acid affords plated cryftals. Regulus of antimony is very fparingly acted on by the acetous acid; infomuch that it might be judged that no action took place, if it did not impart an emetic quality to the fluid. Manganefe is not acted on by this acid but with great difficulty, though repeated diftillations at length combine the two fubftances. It has not been afcertained whether the acetous acid has any action upon wolfram or molybdena.

Zinc an improper material to defend copper veffels.

BOOK II.

PARTICULAR CHEMISTRY.

SECTION VI.

CONCERNING THE PRODUCTS OF THE ANIMAL KINGDOM.

CHAP. I.

A SHORT ENUMERATION OF SUCH ANIMAL SUBSTANCES AS HAVE BEEN EXAMINED BY CHEMISTS.

ANIMAL SUBSTANCES.

Analyfis and arrangement.

THE general ftructure and methods of analyfing animal fubftances have been already noticed. It therefore remains only to enumerate and defcribe the feveral products of this kingdom which have engaged the attention of chemifts. In the arrangement of thefe, as in the vegetable kingdom, we cannot, on account of the imperfect ftate of our knowledge, have recourfe to the nature of their component parts; but fhall ſhall rather attend to the means by which they are reſpectively afforded or obtained. In this way we may conſider the parts of animals as either,

Enumeration.

1. Such as are uſually obtained without deſtroying life. Theſe are milk, eggs, urine, excrement, the matter of perſpiration, ambergris, &c.; wax, honey, gum lac, ſilk, hair, horn, feathers, &c. Or,

2. Such parts of animals as are obtained by deſtroying them, or depriving them of life. Theſe are blood; various ſolids, confounded under the name of fleſh, fat, ſpermaceti; bile, the gaſtric juice, and ſeveral acids; together with calcareous earth, and other ſubſtances, common to the mineral and vegetable kingdoms.

CHAP. II.

CONCERNING MILK, EGGS, HONEY, WAX, LACCA, SILK, HAIR, HORN, ETC.

MILK.

General characters of milk.

MILK is a well known fluid, fecreted in peculiar veffels of the females of the human fpecies, of quadrupeds, and of cetaceous animals, and deftined for the purpofe of nourifhing their young. Its appearance and component parts are not altogether the fame in various fpecies of animals; but the differences have not yet been well afcertained. For this reafon, in treating of milk, our attention will be confined to that of the cow, becaufe the moft abundantly met with. This fluid is of a beautiful opake white colour, nearly as limpid as water, and of a pleafant emulfive tafte. Its appearance on the ftage of a microfcope exhibits an infinity of minute opake globules floating in a tranfparent fluid.

Effects of heat on cows milk.

Cows milk, diftilled on a water bath, affords a taftelefs phlegm of a faint fmell, which is capable of putrefying. A ftronger heat coagulates it. It is fometimes gradually dried into a fubftance which is a kind of faccharine extract, and may again be diffufed in water. By deftructive diftillation, milk affords an acid, a fluid oil, a concrete oil, and volatile alkali. Its refidual coal contains a fmall quantity of vegetable alkali, fome falt of Sylvius, and phofphoric calcareous falt.

When

MILK.

When milk is left to fpontaneous decompofition, at a due temperature, it is found to be capable of paffing through the vinous, acetous, and putrefactive fermentations. It appears however, probably on account of the fmall quantity of ardent fpirit it contains, that the vinous fermentation lafts a very fhort time, and can fcarcely be made to take place in every part of the fluid at once by the addition of any ferment. This feems to be the reafon why the Tartars, who make a fermented wine from mares milk, called koumifs, fucceed by ufing large quantities at a time, and agitating it very frequently.

Fermentation of milk.

Page 482.

When milk is left expofed for fome hours in a ftate of repofe, a fmall quantity of thick fluid rifes to the top, and is known by the name of cream. This contains the fat fubftance called butter, which is afterwards feparated from it by agitation in the act of churning. The remainder afterwards becomes four, and undergoes a coagulation which feparates it into two parts—a folid curd; and a fluid, called ferum or whey. This four whey contains a peculiar acid, called the acid of milk, and likewife a portion of vinegar. The peculiar acid does not rife in diftillation, but may be feparated by evaporating the filtered whey to one eighth; and precipitating the phofphoric falt by the addition of lime-water, which fully faturates its acid: the fluid is then to be diluted with three times its weight of water; and the redundant lime precipitated by faccharine acid, in which operation the excefs of the laft-mentioned acid may be guarded againft by the teft of a fmall portion of lime-water. This purified liquor muft then be evaporated to the con-

Cream.

Butter.

Acid of milk.

7 fiftence

MILK.

Acid of milk.

ſiſtence of honey; and the other foreign ſubſtances it may contain will be ſeparated by the addition of pure ardent ſpirit, which takes up the acid of milk only. The decanted ſolution being then diluted with water, and heated, the ardent ſpirit flies off, and leaves the acid of milk behind, diſſolved in the water.

Combinations with various ſubſtances.

This acid does not afford cryſtals; and, when evaporated to dryneſs, it deliqueſces again by expoſure to air. With vegetable alkali it affords a deliqueſcent ſalt, ſoluble in ardent ſpirit. With mineral alkali it affords a ſalt poſſeſſing the ſame properties. With volatile alkali it produces a deliqueſcent ſalt, which yields much of its alkali by diſtillation before the acid is deſtroyed by heat. With lime, clay, and ponderous earth, it forms deliqueſcent ſalts; but with magneſia it affords ſmall cryſtals, which at length deliqueſce. The acid of milk diſſolves iron and zinc, and produces inflammable air. Copper affords a dark blue ſolution, which does not cryſtallize. Lead is diſſolved after ſome days digeſtion, and affords veſtiges of vitriolic acid. Biſmuth, cobalt, antimony, tin, mercury, ſilver, and gold, are not affected by this acid in a digeſtive or boiling heat. Deſtructive diſtillation decompoſes the acid of milk: water firſt comes over; then a weak acid, reſembling the empyreumatic acid of tartar; afterwards ſome empyreumatic oil, with more of the ſame acid, and alſo fixed air, and the heavy inflammable air. A coal remains in the retort.

Curd.

If any vegetable or mineral acid be added to milk, the curd is ſeparated, and coagulates into one maſs, if the

the mixture be aſſiſted by the application of heat. The curd obtained by means of mineral acid, always manifeſts ſigns of acidity, and is partially ſoluble in boiling water. If any neutral, earthy, or metallic ſalt be added to ſaturation in milk, it likewiſe ſeparates the curd. Sugar and gum-arabic produce a ſimilar effect. Cauſtic alkalis diſſolve the curd, by the aſſiſtance of a boiling heat; and it may again be coagulated by the addition of acids. Curd.

Manufacture of cheeſe:

The coagulation of milk, in the manufacture of cheeſe, is effected by the addition of rennet, which is the infuſion of the ſtomach of a ſucking calf in water, prepared in various ways, according to the fancy of the makers. This fluid ſeems to owe its properties to the gaſtric juice of the animal. The ſeparated curd is wrapped in a cloth with ſalt, and preſſed, to deprive it of the ſuperfluous whey; after which, it is preſerved for ſeveral months or years before it is conſidered as fit for uſe.

—properties.

Cheeſe, when decompoſed by deſtructive diſtillation, affords an alkaline phlegm, an heavy oil, and much volatile alkali. Its reſidual coal is difficult to incinerate, and does not afford fixed alkali. By treating it with the nitrous acid, it is found to contain lime and phoſphoric acid. Cheeſe is not ſoluble in water. Hot water hardens it.

Sugar of milk.

The ſaccharine ſubſtance upon which the fermenting property of milk depends, is held in ſolution by the whey which remains after the ſeparation of the curd in making cheeſe. This is ſeparated by evaporation in the large way, for pharmaceutical purpoſes, in various parts of Switzerland. When the whey has been

MILK.

Sugar of milk.

been evaporated by heat to the confiftence of honey, it is poured into proper moulds, and expofed to dry in the fun. If this crude fugar of milk be diffolved in water, clarified with whites of eggs, and evaporated to the confiftence of fyrup, white cryftals, in the form of rhomboidal parallelopipedons, are obtained.

—Decompofition by heat:

Sugar of milk has a faint faccharine tafte, and is foluble in three or four parts of water. It yields by diftillation the very fame products that other fugars do. It is remarkable, however, that the empyreumatic oil has a fmell refembling flowers of benzoin. Twelve ounces of diluted nitrous acid being poured upon four ounces of finely powdered fugar of milk, in a glafs retort, on a fand-bath, with a receiver annexed, the mixture became gradually hot, and at length effervefced violently, and continued to do fo for a confiderable time after the retort was taken from the fire. It is neceffary, therefore, in making the experiment, to ufe a large retort, and not to lute the receiver too tight to the retort. After the effervefcence had in fome meafure fubfided, the retort was again placed on the fand-bath, and the nitrous acid diftilled off, till the mafs acquired a yellowifh colour. This yellow fluid exhibited no cryftals. Eight ounces more of the fame nitrous acid were therefore added, and the diftillation again repeated, till the yellow colour of the fluid difappeared. The fluid became infpiffated by cooling; it was therefore rediffolved in eight ounces of water, and filtered. Seven drams and a half of a white powder remained on the filter, and the clear folution afforded cryftals of faccharine acid. The mother water was again treated feveral times with nitrous acid, by which

—treatment with nitrous acid.

which means the whole was at length changed into faccharine acid.

Peculiar acid of fugar of milk.

The white powder that remained on the filter was found to be combuftible like oil, in a red-hot crucible, without leaving any mark of afhes behind. It was foluble in fixty times its weight of boiling water; and one fourth part feparated by cooling, in the form of very fmall cryftals. The remaining mafs being then collected, by evaporating the greateft part of the water, left behind a fmall portion of the acid of fugar, of which it had not been fo exactly deprived by edulcoration on the filter. From thefe circumftances it appeared that the white matter was a falt; and, upon examination, it was found to be an acid, poffeffing the following properties:

Combinations.

With all the foluble earths it forms falts infoluble in water. It difengages fixed air from the mild alkalis. With vegetable alkali it forms a cryftallizable falt, foluble in eight times its quantity of boiling water, and feparable for the moft part by cooling. With the mineral alkali it forms a falt which requires only five parts of boiling water for its folution. Both thefe falts are perfectly neutral. When faturated with volatile alkali, it forms a falt which, after being gently dried, has a fourifh tafte. It does not perceptibly act on the metals; but forms with their calces, in folution, falts of very difficult folubility, which are therefore precipitated *.

The principles of milk appear to be united together partly in a chemical, and partly in a mechanical

* On milk and its acid, and on the acid of the fugar of milk, confult the Chemical Effays of Scheele.

MILK.

manner; and the butter feems to rife to the top in confequence of the greater fpecific gravity of the whey through which it is difperfed. Cream confifts of butter mixed with much whey and curd. It is generally thought that the feparation of the butter by churning is effected fimply by the agitation, which caufes the fatty particles to ftrike againft each other, and coagulate into larger maffes. There feems however fome reafon to think that a chemical effect takes place in this operation; in which the intimate mixture of atmofpheric air with the fluid may perhaps have fome effect.

Separation of butter from cream:

—its properties.

Butter appears to be of the nature of fat oils; but is confidered by moft nations as infinitely preferable to them, as an article of food. By diftillation on a water bath it gives out the aqueous fluid which, from the manner of its fabrication, is diftributed through its mafs. Its products by deftructive diftillation nearly refemble thofe of other oils. They confift of an acid of a ftrong and penetrating fmell, a fluid oil, and a concrete oil of the fame fmell as the acid. Thefe oils, like others obtained in fimilar circumftances, may, by repeated rectifications, be converted into volatile oils, of the nature of thofe which are called effential. In other refpects, butter poffeffes the fame properties and may be applied to the fame ufes as fat oils. It becomes rancid by fpontaneous decompofition, which develops its acid; and with fixed alkalis it forms foap.

Eggs.

The eggs of birds confiderably refemble milk in their component parts, though their peculiar ftructure and

MILK.

and organization conftitute a great and effential difference, applicable to the purpofes of generation, into which our prefent views do not require us to proceed. The white of egg does not greatly differ from the curd of milk or cheefe. When it is mixed with water, it forms a coagulum or curd by the addition of acids. Heat coagulates the white of egg, without depriving it of weight; which is a very fingular fact, and has not yet been well explained. The white of egg however appears to differ, in fome refpects, from curd. It is faid to afford a fmall portion of fulphur by fublimation; and it contains the mineral alkali in a difengaged ftate.

Refemblance between white of egg and curd of milk.

The yolk of egg appears to be an animal emulfion, which is diffufible in water. It contains an oil, which may be feparated by drying, and afterwards fubjecting it to preffure.

Yolk of egg.

Honey and wax may be confidered as animal fubftances, becaufe afforded by the bee; though it is not improbable but thefe laborious infects may extract them from the veffels of plants, and depofit them in their hives without alteration.

Honey and wax.

Honey which is purified by folution and cryftallization, perfectly refembles the faccharine juices of vegetables which have undergone the like treatment. It affords the fame product as fugar by deftructive diftillation. Nitrous acid converts it into the faccharine acid, and its aqueous folution is fufceptible of all the ftages of fermentation. It is accordingly, as we have before obferved, made ufe of in the preparation of a vinous liquor.

Purification of honey.

Page 482.

 Wax

WAX.

Distillation of wax.

Wax is a concrete substance, which greatly resembles the more solid fixed oils, and unites with oily substances in all proportions. Its products, by destructive distillation, are the same as those of other fat substances. The concrescible oil obtained by distillation of this substance, is called butter of wax. Bees-wax is of a yellow colour, but becomes white by exposure to air: this effect takes place only at or near the surface or place of contact: for which reason the bleachers of wax find it necessary to renew the surface frequently. This is done either by causing the melted wax to pass through a number of holes in the bottom of a vessel into another vessel of water, by which means it undergoes that kind of division which, in metallic bodies, is called granulation; or it is gently poured upon a wooden cylinder, which is turned round in a vessel filled with water to such a height, that half of the cylinder is immersed. In this way, the wax forms a number of thin flakes, that do not adhere to each other, but may be taken off, and exposed to the action of the air. The dephlogisticated or aërated marine acid bleaches wax very speedily; from which fact it appears that the wax owes its whiteness, and the greater consistency it acquires, to an absorption of the vital part of the atmosphere. Wax seems to differ from tallow, or concrete oil, principally in this circumstance: and this last substance becomes likewise harder and whiter by long exposure to the air, in thin masses: as, for example, when it is spread out upon the surface of water. Wax being already combined with a portion of vital air, does not burn with so luminous a flame as tallow or oil. But it possesses a very great

Butter of wax.

Bleaching.

Difference between wax and tallow.

WAX.

great advantage in the fabrication of candles, which arifes from the circumftance of its freezing point being placed at a confiderably higher temperature than thofe of either of the other two fubftances.

An explanation of the chief advantage of wax candles compared with thofe of tallow.

To explain this advantage, it muft be confidered, that oils do not take fire, unlefs they be previoufly volatilized by heat. The wick of a candle, or lamp, anfwers this purpofe. The oil rifes between the fibres of the wick by the capillary attraction. Heat is applied to the extremity of the wick, which volatilizes and fets fire to a portion of the oil. While this is diffipated by combuftion, another portion paffes along the fibres, and fupplies its place by becoming heated and burned likewife. In this way a conftant combuftion is maintained. It muft be remarked, however, that a candle differs from a lamp in one very effential circumftance, namely, that the oil, or tallow, is liquefied only as it comes to be in the vicinity of the conflagration; and this fluid is retained in the hollow of the part which is ftill concrete, and forms a kind of cup. For this reafon, it is found neceffary that the wick fhould not be too thin; becaufe, in this cafe, it would not carry off the fluid as faft as it becomes fufed; and the confequence would be, that it would run down the fides of the candle: and, as the inconvenience arifes from the fufibility of the oil, it is plain that a more fufible candle will require a larger wick; or that the wick of a wax candle may be made thinner than that of one of tallow.

The difference of effect, in illumination, between a thick and a thin wick, cannot be better fhewn than by remarking the appearances produced by both. When

WAX.

The use and effects of the wick in candles.

a candle with a thick wick is first lighted, and the wick snuffed short, the flame is perfect and luminous, unless its diameter be very great; in which last case, there is an opake part in the middle, where the combustion is impeded for want of air. As the wick becomes longer, the space between its upper extremity and the apex of the flame is diminished; and consequently the oil which issues from that extremity, having a less space of ignition to pass through, is less completely burned, and passes off partly in smoke. This evil continues to increase, until at length the upper extremity of the wick projects beyond the flame, and forms a support for an accumulation of soot, which is afforded by the imperfect combustion. A candle, in this situation, affords scarcely one tenth of the light which the due combustion of its materials would produce; and tallow-candles, on this account, require continual snuffing.—But, on the contrary, if we consider the wax candle, we find that, as its wick lengthens, the light indeed becomes less. The wick however, being thin and flexible, does not long occupy its place in the centre of the flame; neither does it, when there, enlarge the diameter of the flame so as to prevent the access of air to its internal part. When its length is too great for the vertical position, it bends on one side; and its extremity, coming in contact with the air, is burned to ashes; excepting such a portion as is defended by the continual afflux of melted wax, which is volatilized, and completely burned, by the surrounding flame. We see therefore that the difficult fusibility of wax renders it practicable to burn a large quantity of fluid by means of a small wick; and that

WAX. LACCA.

this fmall wick, by turning on one fide in confequence of its flexibility, performs the operation of fnuffing upon itfelf, in a much more accurate manner than it can ever be performed mechanically.

Wax is not foluble in ardent fpirit.

Stick-lac, fhell-lac, and feed-lac:

Lac, or lacca, is a fubftance well known in Europe, under the different appellations of ftick-lac, fhell-lac, and feed-lac. The firft is the lac itfelf, which is a brown femi-tranfparent fubftance, in pretty confiderable lumps, with woody parts adhering to it. Seed-lac is the ftick-lac broken in pieces, and appearing in a granulated form. Shell-lac is the fubftance which has undergone a fimple purification.

—its production.

Lac is the product of an infect *, which depofits its eggs on the branches of a tree called Bihar, in Affam, a country bordering on Thibet, and elfewhere in India. It appears defigned to anfwer the purpofe of defending the eggs from injury, and affording food for the maggot in a more advanced ftate. It is formed into cells, finifhed with as much art and regularity as an honeycomb, but differently arranged; and the inhabitants collect it twice a year, in the months of February and Auguft. For the purification, it is broken into fmall pieces, and put into a canvas bag of about four feet long, and not above fix inches in circumference. Two of thefe bags are in conftant ufe, and each of them held by two men. The bag is placed over a fire, and frequently turned, till the lac is liquid enough to pafs

* For a defcription, confult Kerr, in the Phil. Tranf. vol. lxxi, p. 374.

LACCA. through its pores; when it is taken off the fire, and twifted in different directions by the men who hold it, at the fame time dragging it along the convex part of a plantain tree prepared for that purpofe; and, while this is doing, the other bag is heating, to be treated in the fame way. The mucilaginous and fmooth furface of the plantain tree prevents its adhering; and the degree of preffure regulates the thicknefs of the coating of lac, at the fame time that the finenefs of the bag determines its clearnefs and tranfparency*.

Purification of lac.

Characters.

Lac is not entitled to arrangement either with oils, refins, or gums. It is not foluble either in water, or in fat oils. Some effential oils appear to extract a dilute tincture. The action of the acids upon lac, either when concentrated or diluted, does not feem to be confiderable; but this requires more particular examination, efpecially as far as relates to the nitrous acid. Ardent fpirit acts but feebly on this fubftance. By ftanding upon it in the cold, it forms a clear tincture, apparently by diffolving only a part of its principles; but, when digefted in a moderate heat, the whole of the lac unites with the fpirit, and forms a turbid mixture, or imperfect folution, of a gummy appearance, which does not afterwards become clear. In this way, however, with judicious management, it appears practicable to form a very hard opake varnifh, refembling that of China or Japan. The principal ufe of lac is in the manufacturing of fealing-wax, and in dyeing fcarlet. For this laft purpofe, half a dram of powdered comfrey root is to be boiled in a quart of

Hard varnifh.

* Saunders, in Phil. Tranf. vol. lxxix.

water

LACCA. SILK.

water for a quarter of an hour, and fome powdered gum lac digefted in the decoction for two hours. The tincture appears of a fine crimfon colour; and the remaining lac, if the quantity of liquor has been fufficient, is of a pale ftraw colour. The clear tincture being then poured off, and a folution of alum gradually added, the colouring matter fubfides, in the form of one of the powders called lakes, which amounts to about one-fifth part of the weight of the lac. This fecula is diffolved in warm water, with the addition of a proper quantity of the folution of tin in aqua regia: and the liquor, which is of a fiery red colour, is then to be poured into boiling water, impregnated with falt of tartar, or the mild fixed vegetable alkali. The bath, thus formed, is a good fcarlet dye for woollens, though lefs lively than that of cochineal.

Ufes of lac.

Lewis on Neumann.

Silk is a well-known fubftance, which ferves as a nidus for the chryfalis of the filk-worm. Its extenfive utility, when contrafted with the fmall profpect of advantage which its appearance in the crude ftate feems to afford, may ferve to ftimulate our induftry in the examination of other natural products; many of which, though neglected at prefent, might, on enquiry, be found equally beneficial to fociety. This fubftance feems to hold a middle rank between animal and vegetable matters. It affords volatile alkali by diftillation, and gives out phlogifticated air when treated with nitrous acid. By diftilling the nitrous acid from this fubftance, the acid of fugar is obtained, and likewife a peculiar oil. The phalæna, or moth of the filk-worm, ejects a liquor which appears to contain

Silk, and the acid of filk-worms.

SILK. WOOL. contain a peculiar acid, hitherto little examined. It is obtained in a ſtate of purity by infuſing the chryſalides in ardent ſpirits, and ſubſequent evaporation.

Animal excreſcences. The hair and wool of animals do not ſeem to differ greatly from ſilk. They afford much acid of ſugar, when treated with nitrous acid. It is probable that horns, feathers, and other ſimilar excreſcences of animals, are nearly of the ſame nature.

CHAP.

CHAP. III.

CONCERNING THE EXCREMENTITIOUS PARTS OF ANIMALS.

EXCREMENTITIOUS MATTERS.

Urine and fecal matter.

THE fubftances which are rejected out of the bodies of animals, as ufelefs, are urine, and the fecal matter, or excrement. Thefe differ in the various fpecies of animals, according to their refpective natures and food. But little attention has been paid by chemifts to the urine or excrements of any animals except the human fpecies. We have already had occafion to mention the contents of urine, in treating of the phofphoric acid, in our account of the mineral kingdom; and fhall therefore, in the prefent place, confine our remarks to that peculiar depofition which is known by the name of the urinary calculus, or ftone of the bladder.

Stone of the bladder.

The matter which forms thefe hard concretions is found in all urine; and is depofited by cooling, after the greateft part is evaporated. Heat again diffolves it. In about three hundred times its weight of boiling water it is either totally foluble, or it leaves a very inconfiderable refidue, which feems to be an impurity. As the fluid becomes cold, moft of the calculus is again feparated in fine cryftals. The vitriolic acid diffolves it with effervefcence; the marine acid does not appear to act upon it; and the nitrous acid totally diffolves it. This folution affords no precipitate by the acid of fugar, though the vitriolic acid throws down a fmall portion of felenite: whence it appears that the calculus

EXCREMENTITIOUS MATTERS.

calculus contains fome lime. Pure alkalis diffolve it, as does likewife lime-water. By deftructive diftillation, the calculus affords fluid volatile alkali, and a fublimate of a brown colour, which by a fecond fublimation becomes white. This has a fourifh tafte, is eafily foluble in boiling water, and alfo in ardent fpirit.

Acid of the ftone of the bladder.

From the above, and other experiments, it appears that the calculus confifts of an acid of a volatile nature, together with fome gelatinous or oily matter, and a fmall portion of lime. The acid itfelf may probably be a compound falt with excefs of acid, fimilar to the combinations of mineral alkali and phofphoric acid, vegetable alkali and tartareous acid, and fome others which were confidered as fimple acids, until chemifts had devifed means of feparating their component parts. We fee therefore that the analyfis of the ftone of the bladder has not yet been perfectly made.

Page 215.

Homberg's experiments on human excrement.

However important the knowledge of the component parts of fecal matter may be, to facilitate our acquaintance with the animal fyftem, it may eafily be imagined that the purfuits of the majority of chemifts would be directed to departments of the fcience which promifed effects of a lefs difgufting nature. We poffefs but one fet of experiments made on this fubftance, by Homberg, at the beginning of the prefent century. This philofopher, in confequence of alchemiftical information, inftituted a fet of operations upon the fecal matter of men fed entirely upon bread of Goneffe*, and Champagne wine. He found that,

* A fmall town near Paris, where the moft excellent bread is made.

when

EXCREMENTITIOUS MATTERS.

when recent, it afforded, by diftillation to drynefs, an aqueous, clear, infipid liquor of a difagreeable odour, which contained no volatile alkali; but, by continuing to diftil the refidue by a graduated fire, he obtained fluid and concrete volatile alkali, a fetid oil, and a coaly refidue; fubftances which this imperfect method of analyfis exhibits with every kind of animal fubftance.

Homberg's experiments on the human fecal matter.

The human fecal matter, by lixiviation in water, filtration, and fubfequent evaporation, afforded an oily falt refembling nitre, which was fufed on ignited coals, and took fire when heated to a certain degree in clofed veffels. The fame fecal matter, after it had undergone a complete putrefaction for forty days, in the gentle heat of a water-bath, afterwards afforded by diftillation a colourlefs oil without fmell, which was the thing fought after; but it did not fix mercury, as he had been led to expect.

Imperfect as this examination is, it is rendered ftill lefs generally applicable by the peculiar nature of the aliments from which the matter originated. For it cannot be doubted but that, as the excrements are the refidue of the food taken, they will differ according to the nature of that food; as is indeed fufficiently evinced from their more obvious qualities.

Ambergris.

It is at prefent a general opinion*, that ambergris is an excrementitious fubftance, voided by the phy-

* Chiefly grounded on the enquiries and obfervations of Dr. Swediar, in the Phil. Tranf. for 1783. Mr. Magellan however mentions an undoubtedly vegetable ambergris, gathered from the tree by M. Aublet, and examined by Rouelle. Cronftedt's Mineralogy, p. 458.

feter

EXCREMENTITIOUS MATTERS.

Characters of ambergris.

ſeter macrocephalus, or ſpermaceti whale. Ambergris is found in the ſea, near the coaſts of various tropical countries; and is either white, black, aſh-coloured, yellow, or grey, with black or yellow ſpecks. A ſlight warmth ſoftens it, like pitch; by a greater heat it takes fire; and its chemical products reſemble thoſe of bitumens, among which it has uſually been ranked. Oils diſſolve it; as does likewiſe ardent ſpirit, if its quantity be twelve times that of the ambergris, and its temperature boiling. An addition of eſſential oil promotes the ſolution.

Matter of perſpiration, &c.

Various other matters are rejected from animals; ſuch as the matter of perſpiration, the naſal mucus, tears, &c. But as none of theſe have been examined, we ſhall avoid entering into any detail of their obvious properties.

CHAP.

CHAP. IV.

CONCERNING THE BLOOD, AND THE OTHER FLUID OR SOLID MATTERS, OF WHICH ANIMALS ARE FORMED.

PARTS OF ANIMALS.

THE fluid which firſt preſents itſelf to obſervation when the parts of living animals are divided or deſtroyed, is the blood, which circulates with conſiderable velocity through veſſels called veins and arteries, diſtributed into every part of the ſyſtem. It can ſcarcely admit of doubt but that the component parts, or immediate principles of the blood, muſt differ in the various and exceedingly diſſimilar genera and ſpecies of animals which occupy the land and waters of the globe; and that there are likewiſe differences in the ſtate or compoſition of this fluid in the ſame animal, according to its ſtate of health, as well as the ſituation of the veſſels from which it may be extracted. Theſe differences can be aſcertained only by the united efforts of the anatomiſt and the chemiſt. But as the difficulty and extent of the ſubject have hitherto prevented any conſiderable progreſs, it becomes an object of neceſſity to confine our attention to the blood of man, or of ſuch quadrupeds as afford this fluid in a ſtate not obviouſly different from that of the human ſpecies.

The blood: —differences.

Recent blood is uniformly fluid, and of a ſaline or ſlightly ferruginous taſte. Under the microſcope it appears

PARTS OF ANIMALS.

Characters of the blood.

appears to be compofed of a prodigious number of red globules fwimming in a tranfparent fluid. After ftanding for a fhort time, its parts feparate into a thick red matter, or craffamentum, and a fluid called ferum. If it be agitated till cold, it continues fluid; but a confiftent polypous matter adheres to the ftirrer, which by repeated ablutions with water becomes white, and has a fibrous appearance: the craffamentum becomes white and fibrous by the fame treatment. If blood be received from the vein in warm water, a fimilar filamentous matter fubfides, while the other parts are diffolved. Alkalis prevent the blood from coagulating; acids, on the contrary, accelerate that effect. In the latter cafe the fluid is found to contain neutral falts, confifting of the acid itfelf united with mineral alkali, which confequently muft exift in the blood, probably in a difengaged ftate. Ardent fpirit coagulates blood. On the water-bath, blood affords an aqueous fluid, neither acid nor alkaline; but of a faint fmell, and eafily becoming putrid. A ftronger heat gradually dries it, and at the fame time reduces it to a mafs of about one eighth of its original weight. In this ftate it flightly attracts the humidity of the air, and effervefces with acids; but by a longer expofure, for fome months, it becomes covered with an efflorefcence of mild mineral alkali. By deftructive diftillation this animal fluid affords a watery liquor, holding in folution a neutral falt, with excefs of volatile alkali, but whofe acid part has not been well afcertained: next follows a light oil, a denfe coloured oil, and foul or oleaginous volatile alkali. The refidue is a coal of very difficult incineration, containing common falt, mineral

Habitudes with acids, &c.

Diftillation.

mineral alkali, and an earth, which is probably a combination of lime and phosphoric acid. PARTS OF ANIMALS.

Serum of blood: The serum of blood exhibits marks of a disengaged alkaline salt, and is greatly disposed to putrefy. It unites with water in all proportions, and forms a milky fluid, which may be coagulated by acids or ardent spirit. An increase of temperature causes serum to become consistent, with little or no loss of weight, in the same manner as the white of egg; and it is accordingly used for the same purpose in clarifying liquids. From a variety of experiments, it appears highly probable that white of egg, serum of blood, and the pure curd of milk, do not essentially differ from each other: and to these we may perhaps add the vegetable gluten, which considerably resembles cheese. —resembles white of egg, curd, and vegetable gluten:

Alkalis render the serum of blood more fluid; acids coagulate it, and exhibit the neutral salt they would have produced by direct combination with mineral alkali. The coagulum affords, by distillation, phlegm, mild volatile alkali, and a thick fetid oil; and the residue affords mild mineral alkali. These products are the same as are afforded by the serum itself. —with alkalis and acids:

Serum is also coagulated by ardent spirit, merely by the loss of part of its water. —with ardent spirit: When rendered concrete by heat, and exposed to the action of nitrous acid, it affords phlogisticated air by a slight heat, which is followed by nitrous air; and the residue affords acid of sugar, together with a small portion of acid of apples. —nitrous acid.

Crassamentum. The crassamentum of blood, when treated in the way of distillation, becomes dry and brittle, at the same time that it emits an alkaline phlegm; this is followed by an empyreumatic stinking oil, and concrete volatile

 alkali.

PARTS OF ANIMALS.

alkali. A ſpungy brilliant coal remains, which by treatment with vitriolic acid is found to contain mineral alkali and iron, as appears by the production of Glauber's ſalt and martial vitriol: coaly matter and phoſphorated lime are then left behind.

Fibrous part of blood:

The fibrous matter, which is obtained by waſhing the red part of the blood, reſembles the ſerum in many of its properties; though it differs from it in not being ſoluble in water, in becoming hard by a very gentle heat, and in not combining with alkalis. Acids unite with it, and in particular the nitrous acid diſſolves it, and extricates phlogiſticated and nitrous air; while the reſidue, by evaporation, affords acid of ſugar in cryſtals, a peculiar oil in flocks, and the phoſphoric ſalt of lime. Its volatile products by deſtructive diſtillation are nearly the ſame as thoſe of ſerum: but its reſidue contains no ſalt, except the combination of lime and phoſphoric acid; the other ſalts it might have contained having probably been carried off during the waſhing. Marine acid forms a green jelly with the fibrous parts of the blood.

—with acids.

Deſtructive diſtillation.

Soft parts of animals.

The ſoft and flexible parts of animals appear to be compoſed of principles greatly reſembling thoſe of the blood. When they are boiled in water, the fluid extracts that peculiar animal ſubſtance which is known by the name of jelly or glue. This is afforded by the white parts moſt plentifully, though it is found in almoſt every part of the animal ſolids. Its appearance and inſipidity, together with its other obvious properties, are well known. It is ſoluble in water, in all proportions; is more fluid when hot than when cold.

Jelly or glue.

cold. Alkalis and acids both diffolve it. By fpontaneous decompofition it firft becomes acid, and foon afterwards putrefies. By deftructive diftillation it affords an alkaline phlegm, an empyreumatic oil, and a fmall quantity of volatile alkali. The refidual coal is voluminous, not eafily incinerated, and contains common falt, with the phofphoric falt of lime. The habitude of the nitrous acid with glue, or jelly, is the fame as with other animal fubftances; phlogifticated air and nitrous air are difengaged, and the refidue affords acid of fugar.

Jelly or glue.

Befides the parenchymatous and cellular fubftance of which the mufcles of animals are formed, their veffels contain fluids poffeffed of various properties. Thefe may be obtained by preffure, and the judicious application of water and ardent fpirit, either with or without heat. If flefh be wafhed in cold water, a portion of blood and gelatinous matter, together with faline matter, are extracted: the refidue being digefted in ardent fpirit, is by that means deprived of an extractive or faponaceous fubftance; and fubfequent ebullition in water diffolves the gelatinous part, at the fame time that it deprives it of fuch portions of extract and falt as had been defended from the action of the two former folvents. The fat is alfo liquefied by this operation, and arifes to the furface. By flow evaporation of the aqueous folution, made in the cold, the albuminous part, or ferum, coagulates, and may be feparated on the filter: the filtered liquor will afford its falt by evaporation: the fpirituous folution depofits the extractive matter by evaporation: and the decoction affords the jelly, with the fat oil, which fwims

Analyfis of the flefh of animals.

PARTS OF ANIMALS.

Analysis of the flesh of animals.

at the surface and congeals by cooling. The remaining solid substance consists merely of the fibrous matter, which is white, insipid, and insoluble in water. This affords much volatile alkali, and a very fetid oil, by distillation; and it gives out a large quantity of phlogisticated air when treated with nitrous acid. In a word, it has all the characters of the fibrous part of the blood, and is probably formed by the deposition of that substance*.

The extractive or saponaceous matter obtained by the evaporation of the spirit, is soluble likewise in water; it swells up and liquefies by heat, and emits a smell somewhat resembling that of burned sugar: it is this substance which predominates in the brown crust that covers the surface of roasted meat. The salt afforded by the decoction of flesh has not been perfectly examined; but it seems to consist of the phosphoric acid, united partly with the vegetable alkali, and partly with lime.

Fat of animals.

The fat of animals is a substance of the same nature as those oils which are called fat oils in the vegetable kingdom. Its consistence is various in different animals, and in different parts of the same animal. The fat of the human species and of quadrupeds is consistent, and of a white or yellowish colour; the fat of the internal parts being usually firmer than that which is placed among the muscles. It possesses all the characters of vegetable fat oils; though the crude fat of animals appears to contain a considerable quantity of

* Fourcroy, iv. 427.

muci-

mucilage or jelly peculiar to that kingdom, which may for the moſt part be waſhed off by agitation in a large quantity of hot water. PARTS OF ANIMALS.

Acid of fat.

The acid of fat is conſidered as belonging to the animal kingdom, though indeed it is no leſs abundant in the fat oils of vegetables. It may be obtained by diſtillation. Or otherwiſe a quantity of ſuet may be melted, and mixed with quick-lime: as ſoon as the mixture is cold, it muſt be boiled in a large quantity of water. After filtration and evaporation, the calcareous ſalt formed by the combination of that earth with the acid of the fat, is obtained of a brown colour. A ſlight calcination in a crucible renders it purer, by the deſtruction of a portion of inflammable matter; and by ſolution, filtration, and the addition of a certain quantity of fixed air to precipitate the ſuperfluous lime, a clear ſolution of the acid of fat, neutralized with calcareous earth, is obtained. Evaporation of this fluid affords the pure white ſalt; and this, when diſtilled with the addition of vitriolic acid, affords the acid of fat, which comes over into the receiver, while the lime and vitriolic acid remain in the retort, in the form of ſelenite.

Characters of the acid of fat.

The general characters of the acid of fat are the following:—It is liquid, fuming, and of a penetrating ſmell; decompoſable by fire, which turns it yellow, and extricates or produces fixed air. Blue colours are ſtrongly reddened by it. Water diſſolves it in all proportions. With lime, and alſo with the fixed alkalis, it forms cryſtallizable ſalts, which are not decompoſed by heat. Siliceous earth appears to be

 ſoluble

PARTS OF ANIMALS.

foluble in, or corroded by, this acid; and it acts on feveral of the metals.

Method of obtaining fpermaceti.

Spermaceti is a peculiar fubftance, of the nature of fat oil, which is found in the head of a fpecies of whale. One of thefe fifhes affords fome tons of brains, which are firft grofsly freed from the oil, by draining and preffing; and afterwards more perfectly purified, by fteeping them in a ley of alkaline falt and quick-lime, which converts the remains of the oily matter into foap. The brains being then wafhed with water, appear of a filver whitenefs; and nothing more is then required to complete the preparation, than to cut them in pieces with wooden knives, and fpread them abroad to dry.

Its character:

Good fpermaceti is in fine white flakes, gloffy, and femi-tranfparent; rather unctuous to the touch, though dry, and in fome meafure friable. Its fmell is faintifh, though not difagreeable; and it has fcarcely any tafte, on account of its being either nearly or totally infoluble in the faliva: expofure to the air renders it yellowifh and rancid in procefs of time; and that the more readily in proportion as the original purification has been lefs complete. It may however be rendered white and fweet again, by fteeping it afrefh in cauftic alkali, and wafhing it in water.

— and habitudes.

It is fcarcely, if at all, more combuftible than tallow; and is a much better material for candles, becaufe lefs fufible and greafy. By diftillation it totally rifes, leaving no coal behind; but its component parts do not rife together. Four ounces of this fubftance afforded three ounces and a half of a clear,

clear, yellowish, butyraceous oil, resembling oil of wax in smell, and coagulate in the cold, like that substance; a drachm and a half of the product consisted of phlegm, and the rest was wasted or dissipated in the process *.

Habitudes of spermaceti with various substances.

Water has no other effect upon spermaceti, when boiled with it, than to separate a small quantity of mucilaginous, or perhaps saponaceous matter, which is probably an impurity. Oils dissolve it, by the assistance of heat; hot ardent spirit likewise dissolves it, but lets the greatest part fall upon cooling; ether dissolves it very readily; sulphur combines with this substance in the same manner as it does with fat oils; the nitrous and marine acids have no action on it; concentrated vitriolic acid dissolves it, but lets it fall again by heat.

Conjecture respecting its singular properties. Page 431—433. 516.

It has been conjectured that this singular substance bears the same relation to fat oils as camphor does to the essential oils. Wax appears to have the same relation to fixed oils, as resin has to the essential; that is to say, both have been rendered concrete by the absorption of vital air. But spermaceti and camphor seem to differ in some other leading particular; probably in the absence of acid, or of any basis which can easily be acidified by the action of nitrous or other acids. Much information would no doubt be derived from a careful examination of the products which these several substances afford by combustion.

* Neumann's Chemistry, by Lewis, ii. 422. Fourcroy, iv 447, says that spermaceti forms a soap with caustic alkali; which is contrary to the positive assertion of Neumann, from whom the foregoing part of the text is taken.

PARTS OF ANIMALS.

Bones.

The bones of men and quadrupeds owe their great firmnefs and folidity to a confiderable portion of the phofphoric falt of lime which they contain. When thefe are rafped fmall, and boiled in water, they afford gelatinous matter, and a portion of fat or oil, which occupied their interftices. By deftructive diftillation they afford alkaline phlegm, a fetid oil, and much volatile alkali; leaving a coal not eafily burned. In an open fire, bones are inflamed by virtue of their oil, and emit an offenfive empyreumatic fmell. The white, friable, and incombuftible refidue confifts chiefly of lime and phofphoric acid in combination. It affords a fmall quantity of mild mineral alkali by wafhing with water. This white matter is decompofable by fufion, with mild fixed alkalis, which unite with the phofphoric acid, at the fame time that the fixed air converts the lime into chalk. Acids likewife difengage the phofphoric acid, by uniting with the lime. The nitrous or the vitriolic acids are moft commonly ufed in this procefs.

White refidue.

CHAP. V.

CONCERNING THE BILE, THE GASTRIC JUICE, AND THE ACID OBTAINED FROM ANTS.

THE fluids which remain to be confidered, as compofing part of animals, are the bile, the gaftric juice, and fuch acids as are obtained by treatment of animal matters. ANIMAL FLUIDS.

The bile or gall is a fluid of a yellowifh green colour, exceffively bitter, and of a faint naufeous fmell. It is feparated from the blood in a glandular vifcus, well known by the denomination of the liver, and in moft animals is collected in a veffel called the gall bladder. The gall of oxen is that which chemifts have more particularly examined. Its confiftence is almoft gelatinous; by agitation it forms a froth fimilar to that of a folution of foap. Water diffolves it in all proportions; and this folution produces the fame effect as a folution of foap in fcouring cloths. All the acids decompofe it, and produce a coagulum, which feparates from the watery folution, at the fame time that the acid becomes neutralized by a portion of mineral alkali which unites with it. The coagulum, which may be feparated by the filter, is thick, vifcid, very bitter, and very inflammable. It appears fo far of a refinous nature, as to be totally foluble in ardent fpirit: hence it follows that the bile confifts principally of a foap compofed of this matter and the mineral alkali. It alfo contains a quantity of ferum, which Characters of the bile or gall.

ANIMAL FLUIDS.

which causes it to coagulate by heat, or by the action of ardent spirit, and disposes it to putrefy. Ardent spirit takes up the saponaceous matter, and leaves the serum behind.

Destructive distillation of the bile.

Destructive distillation separates first an aqueous fluid, neither acid nor alkaline, but disposed to putrefy. Nothing else passes over upon the water-bath. The residue is of a dark colour, very tenacious, like pitch, and totally soluble in water. If the distillation be continued with caution, on account of the swelling of the matter, the products are a yellowish alkaline phlegm, empyreumatic oil, much volatile alkali, and the elastic products consist of fixed and inflammable air. A considerable coal remains, which contains mineral alkali, an earth, which is probably a combination of phosphoric acid and lime, and a small portion of iron.

Biliary concretions.

The nature of the biliary concretions which are formed in the gall bladder, has not yet been completely ascertained. These are found sometimes of an irregular texture, and a brown, black, yellowish, or greenish colour; others consist of transparent crystalline laminæ, sometimes radiated from the centre to the circumference. * Two ounces of biliary calculus, of a grey colour without, and brownish green within, were dissolved in twelve times their weight of pure ardent spirit, by the assistance of a moderate heat. The hot solution being filtered, soon deposited, by cooling, a large quantity of laminated white brilliant crystals, resembling the concrete acid of borax. The

* Fourcroy, in the Annales de Chimie, iii. 245.

quantity

quantity amounted to near one fixteenth of the whole calculus; and, upon examination, it poffeffed the following properties:—It was inflammable, and melted by a gentle heat in a fpoon, with a fmell like wax, and cooled into a brittle fubftance of a cryftallized fracture: a fudden heat volatilized the whole. Water had no action upon it when cold; but boiling water caufed it to melt, and float on the furface like an oil, which became concrete by cooling. Cauftic alkalis converted it into foap. Nitrous acid diffolved it quietly, and the addition of water feparated it unaltered. Ardent fpirit diffolved it by heat; but the greateft part was feparated by cooling. Thefe characters indicate that it is a fubftance of the fame nature as fpermaceti. The author * of this valuable difcovery has alfo found that the cryftallized gall ftones contain this matter ftill more abundantly; and that it exifted in confiderable quantity in an human liver which had been expofed to the air for feveral years, and had loft its volatile parts by putrefaction. The affiduous refearches of the fame philofopher into the animal œconomy, have detected the fame fubftance, in a faponaceous form, in bodies which had been many years buried under ground.

Examination of the biliary calculus.

A confiderable number of chemifts have examined the properties of the fluid which appears to be the menftruum of digeftion in the ftomachs of animals. It is certain that in this procefs the aliments become converted into a foft or pulpy mafs, moft probably by the action of a folvent, affifted by their own tendency

The gaftric fluid.

* Fourcroy, in the Annales before cited, iii 120.

to

ANIMAL FLUIDS.

The gastric fluid.

to spontaneous decomposition at the temperature of the body of the animal. The gastric juice procured from the stomachs of animals which have been kept fasting for a considerable time, appears to differ according to their respective natures. It is thought to possess a solvent power upon animal and vegetable substances, without any preference of affinity; but this last circumstance is scarcely probable. A powerful antiseptic quality is reckoned among its attributes; but there are some reasons to think that in graminivorous animals it has the contrary effect. In these last, more especially, it contains a disengaged acid, which seems to be the phosphoric. And upon the whole, it appears that accurate and decisive experiments are still wanting, to determine the nature of this compounded and variable fluid, which is of such important use in the animal œconomy.

Acid of ants.

Of the acids which are considered as belonging more especially to the animal kingdom, we have already attended to those afforded by milk, by fat, by the stone of the bladder, by silkworms, and by the calcination of blood with an alkali, in the preparation of Prussian blue; it therefore remains only for us to give an account of the acid which is afforded by ants. These animals appear to contain a peculiar acid, in a vessel placed near the hinder part of their bodies *, which they eject when enraged; or moisten their fangs with it, to render their bite more painful. The acid may be obtained by distillation of the ants

* Wiegleb's Chemistry, by Hopson, p. 191. On this acid, consult the authors there referred to; and also Fontana, in the Journal de Physique for 1778, part ii.

with

Acid of ants.

with water, and fubfequent preffure of the refidue; or the ants may be tied up in a bag, and twice infufed in hot water; from which infufion as much acid may be diftilled off, as can be had without burning the refidue. It may be purified by faturating it with alkali, filtrating, and evaporating part of the liquor, and diftilling it with half its weight of vitriolic acid: or, more conveniently, the rectified acid may be expofed to the action of a freezing atmofphere, which congeals its aqueous part. This acid has a confiderable refemblance to vinegar when it is diluted. It acts upon, and combines with, alkalis, foluble earths, and metals, and forms peculiar compounds; from which, as well as the order of its elective attractions, its title to be confidered as a diftinct or peculiar acid is eftablifhed.

Deftructive diftillation converts it, like the vegetable acids, into fixed air and inflammable air.

APPENDIX.

APPENDIX.

VARIOUS TABLES USEFUL TO CHEMISTS.

AN ACCOUNT OF THE TABLES.

ACCOUNT OF TABLES.

Table of comparative heats.

TABLE I. contains a ſeries of numbers, expreſſing the comparative heats of bodies. It is copied from Crawford's Experiments and Obſervations on Animal Heat, and the Inflammation of Combuſtible Bodies: London, 1788. The principles on which this Table is formed, have been explained in page 14 of our work, and elſewhere. Nothing more need therefore be ſaid, than that the numbers are here reduced to one common ſtandard of compariſon, water being aſſumed

ACCOUNT OF TABLES.

assumed as unity. As these numbers are deduced from the thermometrical changes undergone by the several bodies in like situations, it is clear that they are of use to indicate those changes, for they will be inversely as the numbers themselves.

Table of weights.

TABLE II. contains the weights of different countries, compared in French and English grains. The value of this Table is obvious, and its character may be seen at page 70.

Table of specific gravities.

TABLE III. exhibits the specific gravities of bodies. In compiling this, I had Brisson's Table at the end of Lavoisier's Traité Elementaire de Chimie, and Muschenbroek's large Table in his Cours de Physique, before me. Some few specific gravities are from other authors, or from experiment. It appeared useless to carry it to more than four places of figures, as the temperatures were not noted, and the various specimens of the same substance often differ in the third figure. These assertions may be thought to require proof: for which reason I shall observe, that by experiment I find that the fifth figure changes at every three degrees of Fahrenheit's thermometer; that lead, tin, and probably all other metals cast out of the same fusion, vary in their specific gravities in the third figure, from circumstances not yet determined, but most likely from the cooling, as is seen in the hardening of steel; that salts, and other artificial preparations, retain more or less of the solvent they were separated from, according to the temperature at which it was effected; and that all parts of organized substances not only differ according to the place of their production, their age, and other circumstances, but

4 like-

likewise from their dryness, moisture, and manner of preservation.

ACCOUNT OF TABLES.

TABLE IV. is taken from the seventh Table of M. Lavoisier's Traité Elementaire. I have in another place * mentioned the strong objections which may be urged against the supposed or implied accuracy of these weights, taken to so many places of figures. In that place, as the object of attention was of a controversial nature, it was proper to speak far within compass; but on the present occasion I must observe, that the most accurate practical chemists would consider a true determination of the specific gravities of aërial fluids to three, or even two places of figures, as a great and valuable acquisition; and though I regard this Table as the best we possess, yet in every instance I doubt the accuracy of the third decimal, and in most of them the second. The column of English grains is substituted instead of the weight of a cubic foot French, which occupies that place in the original.

Table of specific gravities of aerial fluids.

TABLE V. is taken from an excellent Paper of Morveau, in the first volume of the Annales de Chimie. The experiments were made by M. Prieur du Vernois upon the quantity of about 15½ cubic inches French, under the pressure of about 27 French inches of mercury, which answer to nearly 28 English. The manner in which this investigation was conducted, does great credit to both the philosophers who were concerned in it: and the Essay itself, of which this Table is the result, is highly deserving of the attention of those

Table of expansions of airs.

* Preface to the second edition of Kirwan's Essay on Phlogiston, p. x.

ACCOUNT OF TABLES.

ſtudents who wiſh to know the precautions required in theſe delicate experiments, as well as of the ſtrict enquirer who may be deſirous of knowing how far he may depend on the Table itſelf.

Tables of elective attractions.

TABLES VI. to XI. contain in ſubſtance the two Tables of Attractiones Electivæ Simplices which are placed at the end of Bergman's Treatiſe on Elective Attractions, inſerted in the third volume of his Opuſcula, and of which we have had a ſeparate tranſlation into Engliſh. They have been ſince copied into a variety of works, and in moſt with amendments. I have not however ventured to make any alteration, except ſuch as tended to facilitate the inſertion of them in the regular pages of the book, inſtead of adopting the much leſs convenient mode of printing on a large ſheet to be folded out. Hence it is the arrangement of the columns only which is altered, and repetitions avoided; except that in Table VIII. there is a notice that the perlate acid, vital air, the matter of heat, and ſiderite, are left out; the reaſons for which need not be repeated here. Two inducements rendered it moſt eligible to retain the Tables, in other reſpects, the ſame as Bergman left them. The one was, that they might continue to be Bergman's Tables; and the other was, that, if I had been prepared for the arduous taſk of compoſing new Tables, it would have been incumbent on me to have fully ſtated my reaſons for the arrangements I might have adopted; which would have been incompatible with the limits of an Elementary Treatiſe.

With regard to theſe Tables, after earneſtly recommending the ſtudent to peruſe the work from which

Elective attractions.

which they are extracted, it may be obferved, that the fubftances at the heads of the columns are confidered as fimple, with regard to the facts enumerated in thefe fketches, and fo likewife are the fubftances inferted in the columns. The order of pofition denotes that the higher any fubftance ftands in any column, the ftronger is its elective attraction to the fubftance at the head of that column. The under part of each Table exhibits the attractions in the dry way, and muft be confidered as entirely diftinct from the upper part. The horizontal lines between the fubftances in the columns denote that their pofitions, or comparative powers of attraction, are well determined; and, whenever thefe lines are wanting, the pofitions are more or lefs conjectural. Hence it may be feen how much remained to be done at the time the great Bergman conftructed thefe Tables.

TABLE XII. exhibits an approximation towards expreffing the powers of elective attraction between bodies generally applied. It is evident that the Tables of fimple elective attraction exprefs only the order in which the feveral enumerated fubftances furpafs each other in power to adhere to the common fubftance at the head of each column; and do not by any means fhew what will happen when a compound of two principles is applied to another compound alfo containing two principles, as in the cafes called double elective attraction. We cannot, in fact, decide in circumftances of this nature, unlefs we are previoufly acquainted with the fum of the two attractions which tend to preferve the original combinations, and are on that account very expreffively denominated by Mr.

 Kirwan

ACCOUNT OF TABLES.

Kirwan quiefcent attractions; and alfo with the fum of the other two attractions which tend to form new combinations, and are by the fame chemift called the divellent attractions. Thus, for example, if vitriolated tartar, or the compound of vegetable alkali and vitriolic acid, be prefented to the marine falt of lime, we cannot foretel the confequence from any fimple Tables, becaufe thefe will not fhew whether the fum of the powers which tend to preferve the union of the alkali and vitriolic acid, and alfo of the lime and marine acid, be in fact greater or lefs than thofe by which the alkali tends to combine with the marine, and the lime with the vitriolic acid, and form the new compound of falt of fylvius and felenite. Hence we fee the great advantage which the fcience of chemiftry would derive from an extenfive numerical Table founded on experiments of the nature of that now before us. For, in the prefent inftance, we find from the Table, that the vegetable alkali and vitriolic acid adhere with a power expreffed by the number 62; while the lime and marine acid adhere with a power denoted by 20. Thefe are the quiefcent affinities, and their fum is 82. On the other hand, by the fame Table, we find that the attraction between vitriolic acid and lime is 54; and between vegetable alkali and marine acid 32. Thefe are the divellent affinities, and their fum is 86. The latter muft therefore prevail; that is, the combinations will be changed by the vitriolic acid melting with the lime, and forming felenite; while the marine acid combines with the vegetable alkali, and forms falt of fylvius.

TABLE XIII. fhews the proportion of ingredients

ACCOUNT OF TABLES.

Table of ingredients in earths and ſtones.

in earths and ſtones. It is taken from Kirwan's Mineralogy. The extenſive and indefatigable reſearches of this author into all the ſources of chemical information, and the numerous additions he has himſelf made to the ſcience, have enabled him to render this Table more perfect than any which is elſewhere to be met with. Much however remains ſtill to be done, in every part of it, before we can depend on its accuracy throughout; and we hope the author will add the labour of perfecting it, to the other advantages which the ſcientific world has derived from his exertions.

TABLE I. The Comparative Heats of different Bodies.

Inflammable air	21.4000
Dephlogifticated air	4.7490
Atmofpherical air	1.7900
Aqueous vapour	1.5500
Fixed air	1.0454
Arterial blood	1.0300
Water	1.0000
Frefh milk of a cow	.9999
Venous blood	.8928
Phlogifticated air	.7936
Hide of an ox, with the hair	.7870
Lungs of a fheep	.7690
Lean of the beef of an ox	.7400
Alcohol	.6021
Rice	.5060
Horfe beans	.5020
Spermaceti oil	.5000
Duft of the pine tree	.5000
Peas	.4920
Wheat	.4770
Barley	.4210
Oats	.4160
Vitriolic acid	.4290
Pitcoal	.2777
Charcoal	.2631
Chalk	.2564
Ruft of iron	.2500
Wafhed diaphoretic antimony	.2272
Calx of copper, nearly freed from air	.2272
Quicklime	.2229
Cinders	.1923
Afhes of cinders	.1855
Ruft of iron, nearly freed from air	.1666
Wafhed diaphoretic antimony, nearly freed from air	.1666
Afhes of the elm tree	.1402
Calx of zinc, nearly freed from air	.1369
Iron	.1269
Brafs	.1123
Copper	.1111
White calx of tin, nearly freed from air	.0990
Regulus of zinc	.0943
Afhes of charcoal	.0909
Tin	.0704
Yellow calx of lead, nearly freed from air	.0680
Regulus of antimony	.0645
Lead	.0352

TABLE II. The Weights of different Countries.

Place and Denomination of Weight.	Marc	oz.	gros.	grains.	F. grains.	E. grains.
Berlin. The marc of 16 loths		7	5	16	4408	3616.5
Berne. Goldsmiths weight of 8 ounces	1	—	$\frac{1}{2}$	4	4648	3812.2
Berne. Pound of 16 ounces, for merchandise	2	1	$\frac{1}{2}$	6	9834	8067.7
The common pound varies very considerably in other towns of the Canton.						
Berne. Apothecaries weight of 8 ounces	—	7	$5\frac{1}{2}$	26	4454	3654.
Bonn.	—	7	5	$6\frac{3}{4}$	$4398\frac{3}{4}$	3608.6
Bruffels. The marc, or original troyes weight	1	—	—	21	4629	3797.6
Cologn. The marc of 16 loths	—	7	5	11	4403	3612.2
Conftantinople. The cheki, or 100 drachms	1	2	5	28	6004	4925.6
Copenhagen. Goldfmiths weight, commonly fuppofed equal to the marc of Cologn	—	7	$5\frac{1}{2}$	$10\frac{1}{3}$	$4438\frac{1}{3}$	3641.2
Copenhagen. Merchants weight of 16 loths	1	—	—	$22\frac{1}{2}$	$4702\frac{1}{2}$	3857.9
Dantzic. Weight commonly fuppofed equal to the marc of Cologn	—	7	5	$3\frac{1}{2}$	$4395\frac{1}{2}$	3606.
Florence. The pound (anciently ufed by the Romans)	1	3	$\frac{1}{2}$	20	6392	5244.
Genoa. The pefo fottile	1	2	$2\frac{1}{2}$	30	5970	4897.7
Genoa. The pefo groffo	1	2	3	5	5981	4906.7
Hamburgh. Weight; commonly fuppofed equal to the Cologn marc	—	7	5	$7\frac{3}{4}$	$4399\frac{3}{4}$	3609.4
Hamburgh. Another weight	—	7	7	23	4559	3740.2
Liege. The Bruffels marc ufed; but the wt proved	1	—	—	24	4632	3800.1
Lifbon. The marc, or half pound	—	7	$3\frac{1}{2}$	34	4318	3542.4
London. The pound troy	1	4	$1\frac{1}{2}$	1	7021	5760.
London. The pound avoirdupoife	1	6	$6\frac{1}{2}$	6	8538	7004.5
Lucca. The pound	1	3	—	$23\frac{1}{4}$	$6359\frac{1}{4}$	5217.
Madrid. The marc royal of Caftile	—	7	4	8	4328	3550.7
Malta. The pound	1	2	$2\frac{1}{2}$	21	5961	4890.4
Manheim. (The Cologn marc)	—	7	5	$10\frac{1}{4}$	$4402\frac{1}{4}$	3611.5
Milan. The marc	—	7	5	33	4425	3630.2
Milan. The libra groffa	3	—	$7\frac{1}{2}$	—	14364	11784.
Munich. (The Cologn marc)	—	7	5	$11\frac{1}{2}$	$4403\frac{1}{2}$	3612.3
Naples. The pound of 12 ounces	1	2	$3\frac{1}{2}$	27	6039	4954.3
Ratifbon. The weight for gold; of 128 crowns	1	6	—	24	8088	6635.3
Ratifbon. The weight for ducats; of 64 ducats	—	7	2	32	4208	3452.[illegible]
Ratifbon. The marc of 8 ounces	1	—	—	24	4632	3800.1
Ratifbon. The pound of 16 ounces	2	7	$4\frac{1}{2}$	6	10698	8776.5
Rome. The pound of 12 ounces	1	3	$\frac{1}{2}$	14	6386	5239.
Stockholm. The pound of 2 marcs	1	5	7	8	8000	6563.1
Stuttgard. (The Cologn marc)	—	7	5	$11\frac{3}{4}$	$4403\frac{3}{4}$	3612.6
Turin. The marc of 8 ounces	1	—	—	$22\frac{3}{4}$	$4630\frac{3}{4}$	3799.
At Turin they have alfo a pound of 12 of the above ounces. But, in their apothecaries pound of 12 ounces, the ounce is one fixth lighter.						
Warfaw. The pound	1	5	2	12	7644	6271.
Venice. The libra groffa of 12 ounces	1	7	$4\frac{1}{2}$	$25\frac{1}{2}$	$8989\frac{1}{2}$	7374.5
Venice. The pefo fottile of 12 ounces	1	1	$0\frac{1}{2}$	24	5676	4656.5
In the towns dependant on Venice, the pound differs confiderably in each.						
Vienna. The marc of commerce	1	1	1	16	5272	4325.
Vienna. The marc of money	1	1	1	26	5282	4333.3
France. The grain	—	—	—	—	1.	1.21895
England. The grain	—	—	—	—	0.82039	1.

TABLE III. The Specific Gravities of Bodies.

Pure gold caft - -	19258	Onyx - - -	2637
Pure gold hammered	19362	Mufcovy talc - -	2792
Standard gold caft -	17486	Common flate - -	2672
———— hammered	17589	Calcareous fpar - -	2715
Pure filver caft -	10474	Alabafter - -	2730
Pure filver hammered	10511	White marble - -	2716
Standard filver in coin	10391	Lime ftones from -	1386
Crude platina in grains	15602	———— to -	2390
Platina purified and fufed	19500	Ponderous fpar - -	4474
——— hammered -	20337	Fluor fpar - - -	3180
——— drawn into wire	21042	Pumice ftone - -	914
——— laminated -	22069	Green glafs - -	2620
Mercury - -	13568	Englifh crown glafs -	2520
Lead fufed - -	11352	White flint glafs, Englifh	3290
Copper fufed -	7788	Another piece - -	3216
Copper drawn into wire	8878	White flint glafs, for achromatic ufes - -	3437
Brafs caft - -	8396		
Brafs in wire - -	8544	White glafs, French -	2892
Iron caft - - -	7207	Glafs of S. Gobin - -	2488
Iron bar - -	7788	Brimftone - - -	1990
Steel, foft and not hammered - - -	7840	Phofphorus - - -	1714
		Yellow amber - -	1078
Steel hardened - -	7816	Diftilled water -	1000
Tin, Englifh, fufed -	7291	Sea water - - -	1026
Tin hammered - -	7299	Common fpirit of wine	837
Malacca tin fufed - -	7296	Spirit of wine, the pureft which can be had by mere diftillation - -	820
Malacca tin hammered	7306		
Bifmuth - - -	9823		
Nickel - - -	8660	Vitriolic ether - -	739
Arfenic, the regulus -	5763	Nitrous - - -	909
Cobalt - - -	7812	Marine - - -	730
Zinc - - -	7191	Acetous - - -	866
Antimony - -	6702	Concentrated vitriolic acid	2125
Manganefe - -	6850	Concentrated nitrous acid	1580
Wolfram - -	17600	Concentrated marine acid	1194
Diamond - -	3521	Fluor acid - - -	1500
Ruby - -	4283	Oil of olives - -	915
Ruby fpinell - - -	3760	— of fweet almonds -	917
Topaz, oriental -	4011	Linfeed oil - - -	940
Topaz, Brazilian -	3536	Naptha - - -	708
Topaz, Saxon - -	3564	Gum elaftic - - -	933
Sapphire, oriental -	3994	Camphor - - -	989
Emerald - -	2775	Yellow wax - - -	965
Adamantine fpar - -	4180	White ditto - - -	969
Jargon of Ceylon -	4615	Spermaceti - - -	943
Rock cryftal from Madagafcar - - - -	2653	Tallow - - - -	942
		Heart of oak - -	1170
Quartz - - -	2654	Cork - - - -	240
Agate - - -	2590	Egg new laid - -	[illegible]

TABLE IV. The Specific Gravities of Aerial Subſtances; the Barometer ſtanding at 30 Inches, and the Thermometer at + 55°.*

Names of Aerial Subſtances.	Weight of one cubic Inch. French.	Engliſh.	From the Experiments of
	French grains.	Engliſh grains.	
Atmoſpheric air	0.46005	0.45689	M. Lavoiſier.
Phlogiſticated air	0.44444	0.44139	The ſame.
Vital air	0.50694	0.50346	The ſame.
Inflammable air	0.03539	0.03515	The ſame.
Fixed air	0.68985	0.68511	The ſame.
Nitrous air	0.54690	0.54314	M. Kirwan.
Alkaline air	0.27488	0.27299	The ſame.
Vitriolic air	1.03820	1.03109	The ſame.

* Strictly the numbers are 29.84 inches and 54.5 degrees; anſwering to 28 French inches, and 10 deg. of Reaumur.

TABLE V. The Expanſions of Aërial Subſtances by Heat, from the Freezing to the Boiling Points of Water. For every Interval of 20° of Reaumur's, or 45° of Fahrenheit's Thermometer.

Names.	From 32° to 77°.	From 77° to 122°	From 122° to 167°	From 167° to 212°	Total From 32° to 212°
Common air	$\frac{1}{12.67}$	$\frac{1}{5.61}$	$\frac{1}{2.49}$	[$\frac{1}{3.57}$]	$\frac{1}{1.067}$
Vital air	$\frac{1}{22.12}$	$\frac{1}{4.92}$	$\frac{1}{1.53}$	[$3+\frac{1}{1.73}$]	$4+\frac{1}{2.09}$
Phlogiſt. air	$\frac{1}{29.41}$	$\frac{1}{5.41}$	$\frac{1}{1.82}$	[$5+\frac{1}{57.2}$]	$5+\frac{1}{1.062}$
Inflam. air	$\frac{1}{11.91}$	$\frac{1}{6.92}$	[$\frac{1}{6.85}$]	[$\frac{1}{58.82}$]	$\frac{1}{2.55}$
Nitrous air	$\frac{1}{15.33}$	$\frac{1}{9.00}$	$\frac{1}{3.739}$	[$\frac{1}{6.88}$]	$\frac{1}{1.65}$
Fixed air	$\frac{1}{9.049}$	$\frac{1}{5.099}$	$\frac{1}{2.31}$	[$\frac{1}{3.69}$]	$1+\frac{1}{106.3}$
Alkaline air	$\frac{1}{3.58}$	$\frac{1}{1.75}$	$1+\frac{1}{1.35}$	[$3+\frac{1}{4.69}$]	$5+\frac{1}{5.228}$

*** The numbers between brackets are uncertain.

TABLE VI. Simple Elective Attractions.

ACIDS.

In the Humid Way.

V[illegible]triolic Acid.	Nitrous Acid.	Marine Acid.	Fixed Air.	Acid of Borax.	Acid of Amber.	Acetous Acid distilled.
Barytes	Veg. alkali ?	Veg. alkali ?	Barytes	Lime	Barytes	Barytes
Veg. alkali	Min. alkali ?	Min. alkali ?	Lime	Barytes	Lime	Veg. alkali
Min. alkali	Barytes ?	Barytes ?	Veg. alkali	Magnefia	Magnefia	Min. alkali
Lime	Lime	Lime	Min. alkali	Veg. alkali	Veg. alkali	Vol. alkali
Magnefia	Magnefia	Magnefia	Magnefia	Min. alkali	Min. alkali	Lime
Vol. alkali	Vol. alkali	Vol. alkali	Vol alkali	Vol. alkali	Vol. alkali	Magnefia
Clay	Clay	Clay	Clay	Clay	Clay	Clay
Metallic calces	Metallic calces	Metallic calces	Metallic calces	Metallic calces	Metallic calces	Metallic calces
Water	Water	Water	Water	Water	Water	Water
Ardent fpirit	Ardent fpirit	Ardent fpirit	Ardent fpirit	Ardent fpirit	Ardent fpirit	Ardent fpirit
Phlogifton	Phlogifton	Phlogifton		Phlogifton	Phlogifton	Phlogifton
N. B. The fulphureous or volatile vitriolic acid follows the fame order in the humid way.	N. B. The fuming nitrous acid follows the fame order in the humid way.	N. B. The dephlogifticated or aerated marine acid follows the fame order in the humid way.		N. B. The fame order is followed by the acids of fugar or forrel; tartar; and lemon.	The order in which the metallic calces precipitate each other in acids, is the reverfe of that in the column of phlogifton, in Table IX. Confult page 132.	
			In the Dry Way.			
Phlogifton	Phlogifton	Phlogifton	Prussian Acid. In the Humid Way.			
Veg. alkali	Barytes	Barytes	Veg. alkali	Lime	Barytes	Barytes
Min. alkali	Veg. alkali	Veg. alkali	Min. alkali	Barytes	Lime	Veg. alkali
Barytes	Min. alkali	Min. alkali	Vol alkali	Magnefia	Magnefia	Min. alkali
Lime	Lime	Lime	Lime	Veg. alkali	Veg. alkali	Lime
Magnefia	Magnefia	Magnefia	Barytes	Min. alkali	Min. alkali	Magnefia
Metallic calces	Metallic calces	Metallic calces	Magnefia	Metallic calces	Metallic calces	Metallic calces
Vol. alkali	Vol. alkali	Vol alkali	Clay	Vol. alkali	Vol. alkali	Vol. alkali
Clay	Clay	Clay	Metallic calces	Clay	Clay	Clay
		N. B. Aqua regia follows the fame order both in the humid and dry way.	Water	N. B. The fame order both in the humid and dry way is followed by the acids of fpar; of arfenic; of benzoin; of fugar of milk; of fat; and of phofphorus: except that phlogifton occupies the firft place in the dry way with the arfenical acid.		N. B. The fame order both in the humid and dry way is followed by the acids of milk and of ants.

TABLE VII. Simple Elective Attractions.

ALKALIS AND EARTHS.

IN THE HUMID WAY.

Veg. Alkali.	Min. Alkali.	Clay.	Lime.	Barytes.	Magnesia.
Vitriolic acid	This alkali agrees with the vegetable in the order of its attractions, both in the humid and the dry way.	Vitriolic acid.	A. of sugar	Vitriolic acid	Acid of sugar
Nitrous acid		Nitrous a.	Vitriolic a.	A. of sugar	Phosphor. a.
Marine acid		Marine a.	A. of tartar	A. of amber	Vitriolic acid
Acid of fat		A. of sugar	A. of amber	A. of spar	A. of spar
Acid of spar		Arsenical a.	Phosphor. a.	Phosphor. a.	A. of fat
Phosphor. acid		Sparry a.	A. of s. of milk	A. of s. of milk	A. of arsenic
A. of sugar		A. of fat	Nitrous acid	Nitrous acid	A. of s. of milk
A. of tartar		A. of tartar	Marine acid	Marine acid	A. of amber
A. of arsenic		A. of amber	A. of fat	A. of fat	Nitrous acid
A. of amber		A. of s. of milk	A. of spar	A. of lemon	Marine acid
A. of lemon		A. of lemon	A. of arsenic	A. of tartar	A. of tartar
A. of ants	Vol. Alkali.	Phosphor. a.	A. of ants	A. of arsenic	A. of lemon
A. of milk	This alkali agrees with the vegetable in the order of its attractions, both in the humid and dry way: but mere heat expels it from the acids of phosphorus, borax, and arsenic.	A. of ants	A. of milk	A. of ants	A. of ants
A. of benzoin		A. of milk	A. of lemons	A. of milk	A. of milk
Acetous acid		A. of benzoin	A. of benzoin	A. of benzoin	A. of benzoin
A. of s. of milk		Acetous acid	Acetous acid	Acetous acid	Acetous acid
Acid of borax		A. of borax.	Acid of borax	Acid of borax	A. of borax
Vol. vitr. a.		Vol. vitr. a.	Vol. vitr. a.	Vol. vitr. a.	Vol. vitr. a.
Fuming nitr. a.		Fum. nitr. a.	Fum. nitr. a.	Fum. nitr. a.	Fum. nitr. a.
Fixed air		Fixed air	Fixed air	Fixed air	Fixed air
Prussian acid		Prussian acid	Prussian a.	Prussian a.	Prussian a.
Water			Water	Water	
Fat oils			Fat oils	Fat oils	
Sulphur			Sulphur	Sulphur	Sulphur
Met. calces					

IN THE DRY WAY.

Veg. Alkali.	Silex.	Clay.	Lime.	Barytes.	Magnesia.
Phosphor. acid	In the Humid Way.	Phosphor. acid	Phosphor. acid	Phosphor. acid	Phosphor. acid
A. of borax	A. of spar.	A. of borax	A. of borax	A. of borax	A. of borax
A. of arsenic	Veg. alkali	A. of arsenic	A. of arsenic	A. of arsenic	A. of arsenic
Vitriolic acid	In the Dry Way	Vitriolic acid	Vitriolic acid	Vitriolic acid	Vitriolic acid
Nitrous acid	Fixed alkali	Nitrous acid	A. of amber	A. of amber	A. of spar
Marine acid	Phosphor. acid	Marine acid	Nitrous acid	Acid of spar	A. of fat
A. of fat	Calx of lead	A. of spar	Marine acid	Nitrous acid	A. of amber
A. of spar		A. of fat	A. of fat	Marine acid	Nitrous acid
A. of amber		A. of amber	A. of spar	A. of fat	Marine acid
A. of ants		A. of ants	A. of ants	A. of ants	A. of ants
A. of milk		A. of milk	A. of milk	A. of milk	A. of milk
A. of benzoin		A. of benzoin	A. of benzoin	A. of benzoin	A. of benzoin
Acetous acid		Acetous acid	Acetous acid	Acetous acid	Acetous acid
Barytes		Fixed alkali	Fixed alkali	Fixed alkali	Fixed alkali
Lime		Sulphur	Sulphur	Sulphur	Sulphur
Magnesia		Calx of lead	Calx of lead	Calx of lead	Calx of lead
Clay					
Silex					
Sulphur					

TABLE VIII. Simple Elective Attractions.

COMBUSTIBLE SUBSTANCES AND WATER.

IN THE HUMID WAY.

Water.	Sulphur.	Saline Liver of Sulphur.	Ardent Spirit	Ether.
Veg. alkali	Calx of lead	Calx of gold	Water	Ardent ſpirit
Min. alkali	C. of tin	C. of ſilver	Ether	Eſſential oils
Vol. alkali	C. of ſilver	C. of mercury	Eſſential oils	Expreſſed oils
Ardent ſpirit	C. of mercury	C. of arſenic	Volatile alkali	Water
Mild vol. alkali	C. of arſenic	C. of antimony	Fixed alkali	Sulphur
Glauber's ſalt	C. of antimony	C. of biſmuth	Saline hepar	
Ether	C. of iron	C. of copper	Sulphur	
	Veg. alkali	C. of tin		
	Vol. alkali	C. of lead		
	Barytes	C. of nickel		
	Lime	C. of cobalt		
	Magneſia	C. of mangaeſe		
Vitriolic acid		C. of iron		
Vitriolated tartar	Fat oils			
Alum	Eſſential oils	Ardent ſpirit		
Martial vitriol	Ether	Water		
Corroſ. ſublimate	Ardent ſpirit			

Expressed Oil	Essential Oil
Ether	Ether
Eſſential oils	Ardent ſpirit
Fixed alkalis	Fat oils
Vol. alkali	Fixed alkalis
Sulphur	Sulphur

IN THE DRY WAY.

Sulphur.	Saline Liver of Sulphur.
Fixed alkali	Mangaeſe
Iron	Iron
Copper	Copper
Tin	Tin
Lead	Lead
Silver	Silver
Cobalt	Gold
Nickel	Antimony
Biſmuth	Cobalt
Antimony	Nickel
Mercury	Biſmuth
Arſenic	Mercury
	Arſenic

Four of the columns in the original tables of Bergman are omitted in theſe, viz.

The perlate acid; for which ſee page 215.

Vital air, which is ſuppoſed to have an affinity to phlogiſton only.

The matter of heat; for which ſee pages 6. 21.

The ſemimetal ſiderite; for which ſee page 322.

TABLE IX. Simple Elective Attractions.

PHLOGISTON AND METALS.

IN THE HUMID WAY.

PHLOGISTON.	CALX OF GOLD.	C. OF SILVER.	C. OF PLATINA	C. OF MERCURY.	C. OF LEAD.
Nitrous acid	Ether	Marine acid	Ether	Acid of fat	Vitriolic acid
Vitriolic acid	Marine acid	Acid of fat	Marine acid	Marine acid	Acid of fat
Dephl. marine a.	Aqua regia	Acid of ſugar	Aqua regia	Acid of ſugar	A. of ſ. of milk
Arſenical acid	Nitrous acid	Vitriolic acid	Nitrous acid	Acid of amber	A. of ſugar
Phoſphor. acid	Vitriolic acid	A. of ſ. of milk	Vitriolic acid	Arſenical acid	Arſenical acid
	Arſenical acid	Phoſphor acid	Arſenical acid	Phoſphor. acid	Acid of tartar
C. platina	Sparry acid	Nitrous acid	Sparry acid	Vitriolic acid	Phoſphor. acid
C. gold	Acid of tartar	Arſenical acid	Acid of tartar	A. of ſ. of milk	Marine acid
C. ſilver	Phoſphor. acid	Sparry acid	Phoſphor. acid	Acid of tartar	Nitrous acid
C. mercury	Acid of fat	Acid of tartar	Acid of fat	Acid of lemon	Sparry acid
C. arſenic	Pruſſian acid	Acid of lemon	Acid of ſugar	Nitrous acid	Acid of lemons
C. antimony		Acid of ants	Acid of lemons	Sparry acid	Acid of ants
C. of biſmuth		Acid of milk	Acid of ants	Acetous acid	Acid of milk
C. copper		Acetous acid	Acid of milk	Acid of borax	Acetous acid
C. tin		Acid of amber	Acetous acid	Pruſſian acid	Acid of borax
C. lead		Pruſſian acid	Acid of amber	Fixed air	Pruſſian acid
C. nickel		Fixed air			Fixed air
C. cobalt	Fixed alkali				Fixed alkali
C. mangaueſe	Vol. alkali	Vol. alkali			
C. iron					
C. zinc					
Water					

N. B. In the antiphlogiſtic theory, the column intitled *Phlogiſton* being taken in a reverſed order, will expreſs the elective attractions of *Vital Air*.

IN TH[illegible] WAY.

	GOLD.	SILVER.	PLATINA.	MERCURY.	LEAD.
C. of platina	Mercury	Lead	Arſenic	Gold	Gold
C. gold	Copper	Copper	Gold	Silver	Silver
Acid of arſenic	Silver	Mercury	Copper	Platina	Copper
C. ſilver	Lead	Biſmuth	Tin	Lead	Mercury
C. mercury	Biſmuth	Tin	Biſmuth	Tin	Biſmuth
C. arſenic	Tin	Gold	Zinc	Zinc	Tin
C. antimony	Antimony	Antimony	Antimony	Biſmuth	Antimony
C. biſmuth	Iron	Iron	Nickel	Copper	Platina
C. copper	Platina	Mangaueſe	Cobalt	Antimony	Arſenic
C. tin	Zinc	Zinc	Mangaueſe	Arſenic	Zinc
C. lead	Nickel	Arſenic	Iron	Iron	Nickel
C. nickel	Arſenic	Nickel	Lead		Iron
C. cobalt	Cobalt	Platina	Silver		
C. mangaueſe	Mangaueſe		Mercury		
C. iron	Sa. liv. of ſulph	S. l. of ſulph.	S. l. of ſulph.	S. l. ſulph.	S. l. ſulphur
C. zinc		Sulphur		Sulphur	Sulphur

TABLE X. Simple Elective Attractions.

METALLIC SUBSTANCES.

IN THE HUMID WAY.

Calx of Copper.	Calx of Iron.	Calx of Tin.	Calx of Bismuth.	Calx of Nickel.	Calx of Arsenic.
Acid of fugar	Acid of fugar	Acid of fat	Acid of fugar	Acid of fugar	Marine acid
Acid of tartar	Acid of tartar	Acid of tartar	Acid of arfenic	Acid of forrel	Acid of fugar
Marine acid	Vitriolic acid	Marine acid	Acid of tartar	Marine acid	Vitriolic acid
Vitriolic acid	A. of f. of milk	Vitriolic acid	Phofphor. acid	Vitriolic acid	Nitrous acid
A. of f. of milk	Marine acid	Acid of fugar	Vitriolic acid	Acid of tartar	Acid of fat
Nitrous acid	Nitrous acid	Arfenical acid	Acid of fat	Nitrous acid	Acid of tartar
Acid of fat	Acid of fat	Phofphor. acid	Marine acid	Acid of fat	Phofphor. acid
Arfenical acid	Phofphor. acid	Nitrous acid	Nitrous acid	Phofphor. acid	Acid of forrel
Phofphor. acid	Arfenical acid	Acid of amber	Fluor acid	Fluor acid	Fluor acid
Acid of amber	Sparry acid	Sparry acid		A. of f. of milk	A. of f. of milk
Sparry acid	Acid of amber	A. of f. of milk		Acid of amber	Acid of amber
Acid of lemon	Acid of lemons	Acid of lemons		Acid of lemon	Acid of lemon
Acid of ants	Acid of ants	Acid of ants		Acid of ants	Acid of ants
Acid of milk	Acid of milk	Acid of milk		Acid of milk	Acid of milk
Acetous acid	Acetous acid	Acetous acid		Acetous acid	Arfenical acid
Acid of borax	Acid of borax	Acid of borax		Arfenical acid	Acetous acid
Pruffian acid	Pruffian acid	Pruffian acid		Acid of borax	
Fixed air	Fixed air			Pruffian acid	Pruffian acid
Fixed alkali		Fixed alkali		Aerial acid	
Vol. alkali		Vol. alkali		Volatile alkali	Volatile alkali
Fat oils					Unctuous oils
					Water

IN THE DRY WAY.

Copper.	Iron.	Tin.	Bismuth.	Nickel.	Arsenic.
Gold	Nickel	Zinc	Lead	Iron	Nickel
Silver	Cobalt	Mercury	Silver	Cobalt	Cobalt
Arfenic	Manganefe	Copper	Gold	Arfenic	Copper
Iron	Arfenic	Antimony	Mercury	Copper	Iron
Manganefe	Copper	Gold	Antimony	Gold	Silver
Zinc	Gold	Silver	Tin	Tin	Tin
Antimony	Silver	Lead	Copper	Antimony	Lead
Platina	Tin	Iron	Platina	Platina	Gold
Tin	Antimony	Manganefe	Nickel	Bifmuth	Platina
Lead	Platina	Nickel	Iron	Lead	Zinc
Nickel	Bifmuth	Arfenic	Zinc	Silver	Antimony
Bifmuth	Lead	Platina		Zinc	
Cobalt	Mercury	Bifmuth			
Mercury		Cobalt			
Sal. liv of fulph.	S. l. of fulphur	S. l. of fulphur	S. l. of fulph.	S. l. of fulph.	S. l. of fulph.
Sulphur	Sulphur	Sulphur	Sulphur	Sulphur	Sulphur

TABLE XI. Simple Elective Attractions.

METALLIC SUBSTANCES.

IN THE HUMID WAY.

Calx of Cobalt.	Calx of Zinc.	Calx of Antimony.	Calx of Manganese.	Calx of Wolfram.
Acid of sugar	Acid of sugar	Acid of fat	Acid of sugar	Lime
Acid of sorrel	Vitriolic acid	Marine acid	Acid of sorrel	Vegetable alkali
Marine acid	Marine acid	Acid of sugar	Acid of lemon	Volatile alkali
Vitriolic acid	Acid of s. of milk	Vitriolic acid	Phosphoric acid	
Acid of tartar	Nitrous acid	Nitrous acid	Acid of tartar	
Nitrous acid	Acid of fat	Acid of tartar	Fluor acid	
Acid of fat	Acid of sorrel	Acid of sorrel	Marine acid	In the Dry Way.
Phosphoric acid	Acid of tartar	Acid of s. of milk	Vitriolic acid	Fixed alkali
Fluor acid	Phosphoric acid	Phosphoric acid	Nitrous acid	Lime
Acid of s. of milk	Acid of lemon	Acid of lemon	Acid of s. of milk	Calx of iron
Acid of amber	Acid of amber	Acid of amber	Acid of amber	Calx of manganese
Acid of lemon	Fluor acid	Fluor acid	Acid of fat	
Acid of ants	Arsenical acid	Arsenical acid	Arsenical acid	
Acid of milk	Acid of ants	Acid of ants	Acid of ants	This column is additional. It is deduced from De Luyart's Analysis.
Acetous acid	Acid of milk	Acid of milk	Acid of milk	
Arsenical acid	Acetous acid	Acetous acid	Acetous acid	
Acid of borax	Acid of borax	Acid of borax		
Prussian acid	Prussian acid	Prussian acid	Prussian acid	
Aerial acid	Aerial acid	Aerial acid	Aerial acid	
Volatile alkali	Volatile alkali			

IN THE DRY WAY.

Cobalt.	Zinc.	Antimony.	Manganese.	Wolfram.
Iron	Copper	Iron	Copper	Iron
Nickel	Antimony	Copper	Iron	Silver
Arsenic	Tin	Tin	Gold	Tin
Copper	Mercury	Lead	Silver	Lead
Gold	Silver	Nickel	Tin	Antimony
Platina	Gold	Silver		Bismuth
Tin	Cobalt	Bismuth		Manganese
Antimony	Arsenic	Zinc		Gold
Zinc	Platina	Gold		Platina
	Bismuth	Platina		
	Lead	Mercury		
	Nickel	Arsenic		
	Iron	Cobalt		
Saline liv. of sulph.		Sal. liv. of sulphur	Sal. liv. of sulphur	
Sulphur		Sulphur		

TABLE XII. Numerical Expression of Attractions by M. Morveau.

	Vitriolic Acid.	Nitrous Acid.	Marine Acid.	Acetous Acid.	Aerial Acid or Fix. Air.
Ponderous earth	65	62	36	29	14
Vegetable alkali	62	58	32	26	9
Mineral alkali	58	50	28	25	8
Lime	54	44	20	19	12
Volatile alkali	46	38	14	20	4
Magnesia	50	40	16	17	6
Argil. earth	40	36	10	15	2

TABLE XIII. Of the Proportion of Ingredients in Earths and Stones.

Calcareous Genus.

100 Parts.	Calcar.	Argill.	Silex.	Mag.	Wat.	Iron.
Calcareous spar -	55	- -	- -	—	11	—*a*
Gypsum - -	32	- -	- -	—	38	—*b*
Fluor - - -	57	- -	- -	—	—	—*c*
Tungsten - -	50	- -	- -	—	—	—*d*
Compound spar -	60	- -	- -	35	—	5*e*
Cruetzenwald stone	75	- -	-	12	—	3*f*
Calcareous marle -	50 to 75	20 to 30	20 to 30	—	—	—*g*
Margodes - -	50	32	15	—	—	2
Stellated spar -	66	- -	30	—	—	3
Calcareous grit or sand stone	50	- -	- -	—	—	—*h*
Swine stone - -	95	- -	- -	—	—	—*i*
Pyritaceous limestone	75	14	- -	—	—	4*k*
Martial tungsten -	- -	- -	- -	—	—	0*l*

a And 34 fixed air.——*b* And 30 vitriolic acid.——*c* 43 acid and water.——*d* 50 acid and iron.——*e* Both earths mild.——*f* Ditto.——*g* And water.——*h* Or more; remainder, silex, argill. and iron.——*i* And petrol.; remainder, argill. and iron.——*k* And 7 quartz and sulphur, that is, 25 pyrites.——*l* By the dry way only 30, and 50 tungsten.

Barytic or Ponderous Genus.

100 Parts.	
Mild barytes	78 Earth, 20 fixed air, 2 baroselenite.
Baroselenite	84 Earth, 13 vitriolic acid, and 3 water.
Hepatic stone	33 Baroselenite, 33 silex, 22 alum, 7 gypsum, 5 petroleum.

 Muriatic

Muriatic or Magnesian Genus.

100 Parts.	Silex.	Calc.	Magnefia.	Argill.	Water.	Iron.
Mild magnefia - -	—	—	48	—	22	—*
Keffekil - - -	50	—	50	—	—	—
Steatites - - -	80	—	17	2	—	1
Argillaceous fteatites -	72	—	17	11	—	—
Chalk of Briançon -	70	—	17	11	—	—†
Soap rock - -	70	—	17	13	—	—
Afbeftos - -	63	11	20	4	—	2‡
Martial afbeftos - -	62	12	13,7	1,7	—	10,6
Suber montanum - -	59	11	24	2,4	—	3,6‖
Amianthus - -	64	6,9	18,6	3,3	—	1,2§
Serpentine - -	45	—	23	18	12	3
Talc, Mufcovy - -	50	—	45	5	—	—

Talc, Venetian - - a larger portion of argill. and fmaller of magnefia.

Note, The magnefia and calcareous earths are in a mild ftate, in all the above ftones.

* At a medium, and 3[illegible] fixed air.——† And 2 of talc.——‡ At a medium.——‖ At a medium.——§ And 6 barytes.

Argillaceous Genus.

100 Parts.	Silex.	Argil.	Calcareous	Magnefia.	Iron.	Water.
Pure clay, dry -	63	37*	—	—	—	—
Argillac. marl, dry	46	27	25 †	—	—	—
Fullers earth -	53	18	5	3	4	17 ‡
Pouzzolana - -	57	20	6	—	20	—
Tripoli - -	90	7	—	—	3	—
Pure mica -	38	28	—	20	14 ‖	—
Martial mica -	3[illegible],5	25,5	—	18	22	—
Roof flate or fhiftus	46	26	4 mild	8 mild	14	—
Flagft. or argill. fhift.	36	56	—	—	4	—
Horn-ftone -	37	22	2	16	23	—
Killas - -	60	25	—	9	6	—
Toadftone -	63	14	7	—	16	—
Zeolyte - -	60	20	8	—	—	12 §
Pitch-ftone -	65	16	—	—	5	14 ¶

Gronften - - Horn-ftone and mica, or horn-ftone and fhoerl.

Stelliten - - Mica, quartz and argill.

Binda - - Horn-ftone, mica, fhoerl, quartz, and pyrites.

Growan - - Argill, mica, and quartz.

* At a medium, when perfectly dry, 6[illegible] filiceous.——† Mild at a medium. ‡ And marine acid at a medium.——‖ White calx of iron.——§ At a medium.——¶ And air.

Siliceous

Siliceous Genus.

100 Parts.	Silex.	Argil	Calcar.	Magn.	Iron.
Cryſtal - - -	93	6	1	—	—
Flint - - .	80	18	2	—	—
Petroſilex - -	72	22	6	—	—
Jaſper - - -	75	20	—	—	5
Chalcedonian - -	84	16	—	—	—
Ruby - - -	39	40	mild [illegible]	—	10
Topaz - - -	39	46	ditto 8	—	6
Hyacinth - - -	25	40	dit. 20	—	13
Emerald - - -	24	60	8	—	6
Sapphire - -	35	58	5	—	2
Chryſopraſium - -	95	—	1,7	1,2	0,4 *a*
Lapis lazuli - .	—	—	—	—	— *b*
Felt ſpar - - -	67	14	—	8	— *c*
Veſuvian garnet -	55	39	6	—	—
Garnet - - .	48	30	12	—	10
Martial garnet - -	43,6	27,6	10	—	19
Shoerl tranſparent .	48	40	5	1	5
Shoerl black - -	58	27	5	1	5
Bar ſhoerl - -	61,6	6,6	21,6	5	1,6 *d*
Tourmaline - -	37	45	13	—	5 *e*
Baſaltes - -	52	15	8	2	25
Rowley ragg - -	47,5	32,5	—	—	20
Comp. and cellular lava	47	30	5	—	18
Vitreous ditto - .	49	35	4	—	12
Another from Lapari -	69	22	—	—	9
Black agate of Iceland nearly as the above	—	—	—	—	—
Pumice ſtone - -	84 or 90	—	—	6 to 15	— *f*
Martial muriatic ſpar	50	—	—	30 mild	20 *g*
Turkey ſtone - -	70	5	mild 25	—	— *h*
Ragg ſtone - -	70	5	dit. 20	—	5 *i*
Siliceous grit, with calcareous cement	62,5	—	do. 37,5	—	—
Siliceous ditto, with argillaceous cement	77	20	—	—	3 *k*
Ditto, with ferruginous cement - -	80	5	—	—	15 *l*

a [illegible],6 copper, and ſparry acid.——*b* 8[illegible] martial fluor, 2[illegible] gypsum, as I believe.——*c* 11 ponderous.——*d* 5 water.——*e* At a medium. *f* Remainder calcareous.——*g* As I believe.——*h* As I believe. *i* As I believe.——*k* As I believe——*l* As I believe.

Granite

Siliceous Genus continued.

Granite - -	Quartz, felt ſpar and mica. Quartz, felt ſpar and ſhoerl.
Stellſten - - Granitello - -	Quartz and mica.
Rapakivi - - Granitone - -	Felt ſpar and mica.
Murkſten - - Norka - -	Quartz, garnet, and mica.
Porphyry - -	Jaſper, chert, lava, ſhoerl containing quartz, felt ſpar, ſhoerl, mica, or ſerpentine in a cryſtalline form.
Pudding ſtone - -	Jaſper, chert, ſiliceous grit, or lava, containing pebbles of an oval form.
Siliceous breccias -	The ſame ground and contents, but in angular forms.
Gneiſs - -	Quartz, mica, ſteatites. Quartz, mica, ſerpentine. Quartz, mica, ſhoerl, ſteatites, or ſoap rock. Quartz, felt ſpar, mica, ſerpentine.
Amygdaloides - -	Jaſper, or chert, containing ſpar or ſerpentine.
Metallic rock of Born	Quartz, clay, and ſteatites, and felt ſpar ſometimes.
Variolite - -	Serpentine, containing various ſtones.

Proportion of Ingredients in Natural Salts.

Salts.	Acids	Alka.	Earth	Water.	
Tartar vitriolate -	31	63	—	6	
Glauber's ſalt -	14	22	—	64	
Vitriolic ammoniac	42	40	—	18	
Epſom - -	24	—	19	57	
Alum - -	24	—	18	58	
Vitriol of iron -	20	—	—	55	25 iron
Ditto of copper -	30	—	—	43	27 copper
Ditto of zinc -	22	—	—	5[illegible]	20 zinc.
Nitre - -	30	63	—	7	
Cubic nitre - -	29	50	—	21	
Nitrous ammoniac	46	40	—	14	
Nitrous ſelenite -	33	—	32	35	
Ditto Epſom -	36	—	27	37	
Salt of Silvius -	30	63	—	7	
Common ſalt -	33	50	—	17	
Sal ammoniac -	52	40	—	8	
Marine ſelenite -	42	—	38	20	
Borax purified -	34	17	—	47	

INDEX.

A.

B.

Jelly,

I N D E X.

Smell,

THE END.

5/19/86