











# CHEMICAL ESSAYS.

BY

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## A D V E R T I S E M E N T

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## ADVERTISEMENT.

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many branches of chemistry since the *Institutiones Metallurgicæ*, and the Plan of Chemical Lectures were first printed, but I have no inclination to revise them; they will be candidly read with a reference to the time when they were composed. I do not recollect what motive induced me to write the Metallurgic Institutes in Latin, unless it was the vanity of thinking, that when I had treated the other parts of Chemistry in the same manner, the work might stand a chance of finding its way into foreign countries. I had written several chapters *de Aere communi-fixo-inflammabili; de Igne; de Aqua; de Terra calcaria, vitrescibili, &c.* much about the

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period

period in which the Metallurgic Institutes were finished: but my attention being soon after called to other pursuits, I gave up the design which I had formed, of expressing in a connected series of propositions what was then scientifically known in Chemistry; and what I had written, with this view, shared the fate of my other chemical manuscripts when I determined last year to quit this favourite study.



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IV. Some Remarks on the Effects of  
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sophical Transactions, 1771.

V. A



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## ESSAY I.

*Observations on the Sulphur Wells at  
HARROGATE, made in July and  
August, 1785.*

**I**N 1733, when Doctor SHORT first published his Treatise on Mineral Waters, there were only three sulphur wells at Harrogate; there are now four. I made some inquiry respecting the time and occasion of making the fourth well, and received the following account from an old man, who was himself principally concerned in the transac-  
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tion. About forty years ago, a person who, by lease from the Earl of *Burlington*, had acquired a right of searching for minerals in the forest of *Knareborough*, made a shew as if he had a real intention of digging for coal, on the very spot where the three sulphur wells were situated. This attempt alarmed the apprehensions of the inn-keepers and others at *Harrogate*, who were interested in the preservation of the wells : they gave him what legal opposition they could, and all the illegal that they durst. At length, for the sum of one hundred pounds, which they raised amongst themselves, the dispute was compromised, and the design real or pretended of digging for coal was abandoned. Sulphur water, however, had risen up where he had begun to dig. They inclosed the place  
with

with a little stone edifice, and putting down a bafon, made a fourth well. By a clause in the act of parliament for incloſing Knareſborough Forest, paſſed in 1770, it is rendered unlawful for any perſon whatever to ſink any pit, or dig any quarry or mine, whereby the medicinal ſprings or waters at Harrogate may be damaged or polluted; ſo that no attempts of the kind above-mentioned need be apprehended in future.

This fourth well is that which is neareſt to one of the barns of the Crown-Inn, being about ten yards diſtant from it. In digging, a few years ſince, the foundation of that barn, they met with ſulphur water in ſeveral places. At a very little diſtance from the four wells there are two others of the ſame kind; one in the yard of the Half-Moon-Inn, diſ-



covered in digging for common water in 1783, and another which breaks out on the side of the rivulet below that Inn. On the banks of that rivulet I saw several other sulphureous springs: they are easily distinguished by the blackness of the earth over which they flow.

On the declivity of a hill, about a quarter of a mile to the west of the sulphur wells at Harrogate, there is a bog which has been formed by the rotting of wood: the earth of the rotten wood is in some places four feet in thickness, and there is a stratum consisting of clay, and small loose decaying sand-stones, every where under it. The hill above is of grit-stone. In this bog there are four more sulphur wells; one at the top, near the rails which separate the bog from the Common; and three



at the bottom, though one of these, strictly speaking, is not in the bog, but at the side of it in the stratum on which the bog is situated, and at the distance of a yard or two from a rivulet of fresh water, which runs from thence to Low Harrogate, passing close to the side but above the level of the sulphur wells of that place. On the other side of the hill, above the bog, and to the west of it, there is another sulphur well on the side of a brook; and it has been thought that the wells both at Harrogate and in the bog are supplied from this well. In a low ground, between High Harrogate and Knaresborough, there is a sulphur well; another to the north of it in Bilton Park, at about the distance of a mile; and another to the south of it, at a less distance, was discovered this

year in digging for common water by a person of the name of *Richardson*; and, lastly, there is another at a place called Hookstone Crag: none of these last-mentioned wells are above two miles distant from High Harrogate; and by an accurate search a great many more might, probably, be discovered in the neighbourhood.

It is not unusual to dig within a few yards of any of these sulphur wells, and to meet with water which is not sulphureous. I ordered a well to be dug in the fore-mentioned bog, sixteen yards to the south of the sulphur well which is near the rails, and to the same depth with it; the water with which it was presently filled was chalybeate, but in no degree sulphureous. I had another well dug, at about thirty yards distance from the three sulphur wells  
which

which are situated at the lower extremity of the bog; this well, by the declivity of the ground, was ten or twelve feet below their level, but its water was not sulphureous. From the first well which I dug, it is evident, that every part of the bog does not yield sulphur water; and from the second, which was sunk into the clay, it is clear that every part of the stratum on which the bog is placed does not yield it, though one of the wells is situated in it.

The sulphur wells at Harrogate are a great many feet below the level of those in the bog; but they communicate with them, if we may rely on what Doctor *Short* has told us—  
 “ That about the beginning of this century, when the concourse of people was very great to the Spaw at Harrogate, one *Robert Ward*, an old  
 B 4 man,

man, made a bafon in the clay under the mofs of a bog where the ftrongeft and briskeft of thefe fulphur fprings rife, and gathered half an hogfhead of water at a time for the ufe of the poor; but when he laded this he almoft dried the three fulphur wells at the village, whence it is evident, that all have the fame origin and communicate with one another.” By converfing with fome of the oldeft and moft intelligent people at Harrogate, I could not find that they entertained any opinion of the water at the bog having a communication with that at the Spaw. This circumftance might eafily be afcertained; and, if the fact fhould be contrary to what Doctor *Short* fupposed, the wells at the bog ought to be covered from the weather as thofe at the village are; they would by this mean  
yield

yield great plenty of water for the baths which are wanted by invalids, and which are often very scantily supplied by the wells at Harrogate, notwithstanding the attention which is used in preserving the water which springs at the four wells, by emptying them as often as they become full during both the day and night time. And indeed it is surprising, that the well on the side of the rivulet below the Half-Moon-Inn, which is so well situated for the purpose, has never been inclosed for the furnishing sulphureous water for the baths. The present mode of carrying the water in casks to the several houses where the persons lodge who want to bathe in it, is very troublesome, and the water thereby loses of its virtue. Some of the wells about the village, that for instance which has been discovered



discovered at the Half-Moon-Inn, the water of which, I believe, springs from a different source from that which supplies the four sulphur wells, should be either enlarged to a greater horizontal breadth, or sunk to a greater depth, in order to try, by one or both of these ways, whether the quantity and strength of the water might not be increased; and if that should, as it probably would be the case, one or more baths might be erected after the manner of those at Buxton and other places; or, by proper additional buildings, warm bathing in sulphureous water might be practised, as is done in common water in the bagnios in London. The saltiness of the sulphureous water, if that should be thought useful, might easily be made even greater than that of sea water, by adding a quarter  
of



of a pound of common salt to every gallon of the water used in forming a bath. The waters at Harrogate, though they have long been very beneficial, have not yet been rendered so useful to mankind, as an intelligent and enterprising person might make them. The alternate strata of sand, stone, and shale, which compose the lower hills near the wells at Harrogate, dip very much, as may be seen in a stone quarry about two hundred yards from the wells; and the same circumstance may be observed in dry weather, in following the bottom of the brook from the village up to the bog; and hence, if there be a communication between the waters of the bog and of the village, as Doctor SHORT asserts, it is probable, that the same stratum of shale which is seen at the bottom

bottom of the wells at the village, breaks out again at the bog above the village, and that the water finds its way from the bog to the village through the crevices of that stratum.

After having observed, as carefully as I could, the number and situation of the sulphur wells about Harrogate, I took notice of the temperature of the four at the village. In the month of June, 1780, when the thermometer in the shade was  $72^{\circ}$ , and the pump water at the Granby-Inn, the well of which is fifty feet deep, was  $48^{\circ}$ , the strongest of the sulphur wells, being that of which invalids usually drink, was  $50^{\circ}$ . On the 29th of July in this year, after the earth had been parched with drought for many months, the heat of the strongest well was  $54^{\circ}$ ; the  
water

water of the Granby pump was on the same day  $48^{\circ}$ , and the heat of the air in the shade  $76^{\circ}$ . Doctor WALKER, who has lately written a treatise on Harrogate water, says, that the heat of this spring was  $48^{\circ}$ , when that of an adjoining rivulet was  $53^{\circ}$ . And I have little doubt in believing, that if the experiment was made in cold weather, the temperature of the same well would be found to be several degrees below  $48$ . This variation of temperature in the sulphur water indicates its springing from no great depth below the surface of the earth; or at least it indicates its having run for a considerable distance in a channel so near to the surface of the earth, as to participate of the changes of temperature, to which that is liable from the action of the sun. But the heat of the  
sulphur

sulphur water is not only variable in the same well, at different times, but it is not the same in all the wells at the same time. If we call the strongest well the first, and reckon the rest in order, going to the right, the third well, which is reckoned the next strongest, was  $57^{\circ}$  hot when the first well was  $54^{\circ}$ . In support of the conjecture that the sulphur water of the strongest well would in a cold season make the thermometer sink below  $48^{\circ}$ , which is the constant temperature of springs situated at a great depth in the earth in this country, it may be observed, that though the first and the third well are never frozen, yet the second and fourth well are frozen in severe weather. When the second and the fourth well are covered with ice, it is probable, that the first and the third have a temperature

rature far below  $48^{\circ}$ ; but that the sea salt, which is more abundant in them than in the other two wells, and which of all salts resists most powerfully the congelation of the water in which it is dissolved, preserves them from being frozen in the coldest seasons incident to our climate.

As the temperature of these four wells is not the same in all of them at the same time, nor invariable in any of them, so neither does there seem to be any uniformity or constancy in them, with respect to the quantity of salt which they contain. The salt with which they are all impregnated is of the same kind in all, and it is almost wholly common salt; and though the quantity contained in a definitive portion of any one of the wells is not, I think, precisely the same



same at all seasons of the year, yet the limits within which it varies are not, I apprehend, very great. A method is mentioned in the LXth volume of the Philosophical Transactions, of estimating the quantity of common salt dissolved in water, by taking the specific gravity of the water: this method is not to be relied on, when any considerable portion of any other kind of salt is dissolved along with the sea salt; but it is accurate enough to give a good notion of the quantity contained in the different wells at Harrogate. On the 13th of August, after several days of rainy weather, I took the specific gravities of the four sulphur wells at the village, the drinking well being the first.—Rain water 1.000; first well 1.009; second well 1.002; third well 1.007; fourth well



well 1.002. By comparing these specific gravities with the table which is given in the LXth volume of the Transactions, it may be gathered, that the water of the first well contained  $\frac{1}{72}$  of its weight of common salt; that of the second and fourth,  $\frac{1}{256}$ ; and that of the third,  $\frac{1}{84}$ . After four days more heavy rain I tried the strongest well again, and found its specific gravity to be 1.008. It is worthy of observation, that the water, as it springs into the first and third well, is quite transparent, but usually of a pearl colour in the second and fourth, similar in appearance to the water of the first or third well after it has been exposed a few hours to the air; hence it is probable, that the external air has access to the water of the second and fourth well before it springs up into the

bason. A great many authors have published accounts of the quantity of common salt contained in a gallon of the water of the strongest well; they differ somewhat from each other, some making it more, others less, than two ounces. These diversities proceed either from the different care and skill used in conducting the experiment; or from a real difference in the quantity of salt with which the water is impregnated at different seasons of the year. The medium quantity of salt contained in a gallon falls short of, I think, rather than exceeds two ounces. The sea water at Scarborough contains about twice as much salt as is found in the strongest sulphur well at Harrogate. The sulphur wells at the bog are commonly said to be sulphureous, but not saline. This, however,

however, is a mistake; they contain salt, and salt of the same kind as the wells at the village. I could not distinguish the kind of salt by the method in which I had estimated the quantity contained in the sulphur wells; I therefore evaporated a gallon of the water of the well in the bog which is near the rails, and obtained a full ounce of common salt, of a brownish colour: the colour would have gone off by calcination. In what degree the medicinal powers of Harrogate water depend on its sulphureous, and in what degree on its saline impregnation, are questions which I meddle not with: I would only just observe on this head, that any strong sulphureous water, such as that of Keddlestone in Derbyshire, or of Shap in Westmoreland, which naturally contains little

or no sea salt, may be rendered similar to Harrogate water, by dissolving in it a proper proportion of common salt. The four sulphur wells at Harrogate are very near to each other; they might all be included within the circumference of a circle of seven or eight yards in diameter; yet, from what has been said it is evident, that they have not all either the same temperature, or the same quantity of saline impregnation. This diversity of quality, in wells which have a proximity of situation, is no uncommon phenomenon; and though at the first view it seems to be surprising, yet it ceases to be so on reflection: for the waters which feed wells so circumstanced, may flow through strata of different qualities situated at different depths, though in the same direction; or  
 through

through strata placed both at different depths, and in different directions; and that this is the case at Harrogate is probable enough, there being hills on every side of the hollow in which the village is placed.

With respect to the sulphureous impregnation of these waters, I made the following observations.

The inside of the bason, into which the water of the strongest well rises, is covered with a whitish pellicle, which may be easily scraped off from the grit-stone of which the bason is made. I observed, in the year 1780, that this pellicle on a hot iron burned with the flame and smell of sulphur. I this year repeated the experiment with the same success; the substance should be gently dried before it is put on the iron. I would further observe, that the sulphur is



but a small part of the substance which is scraped off. That I might be certain of the possibility of obtaining true palpable sulphur from what is scraped off from the bason, and at the same time give some guess at the quantity of sulphur contained in it, I took three or four ounces of it, and having washed it well, and dried it thoroughly by a gentle heat, I put two ounces into a clean glass retort, and sublimed from it about two or three grains of yellow sulphur. This sulphur, which stuck to the neck of the retort, had an oily appearance; and the retort, when opened, had not only the smell of the volatile sulphureous acid, which usually accompanies the sublimation of sulphur, but it had also the strong empyreumatic smell which peculiarly appertains to burnt oils; and it retained



tained this smell for several days. It has been remarked before, that the salt separable from the sulphur water was of a brownish colour; and others, who have analysed this water, have met with a brown substance, which they knew not what to make of; both which appearances may be attributed to the oil, the existence of which was rendered so manifest by the sublimation here mentioned. I will not trouble the Society with any conjectures concerning the origin of this oil, or the medium of its combination with water; the discovery of it gave me some pleasure, as it seemed to add a degree of probability to what I had said concerning the nature of the air with which, in one of my Chemical Essays, I had supposed Harrogate water to be impregnated. I will again take the

liberty of repeating the query which I there proposed. “ Does this air, and the inflammable air separable from some metallic substances, consist of *oleaginous* particles in an elastic state?” When I ventured to conjecture, in the Essay alluded to, that sulphureous waters received their impregnation from air of a particular kind, I did not know that Professor *Bergman* had advanced the same opinion, and denominated that species of air, Hepatic Air. I have since then seen his works, and very readily give up to him not only the priority of the discovery, but the merit of prosecuting it. And though what he has said concerning the manner of precipitating sulphur from these waters can leave no doubt in the mind of any chemist concerning the actual existence of sulphur in them; yet

yet I will proceed to the mention of some other obvious experiments on the Harrogate water, in support of the same doctrine.

Knowing that, in the baths of Aix-la-Chapelle, sulphur is found sticking to the sides and top of the channel in which the sulphureous water is conveyed, I examined with great attention the sides of the little stone building which is raised over the basin of the strongest well, and saw them in some places of a yellowish colour: this I thought proceeded from a species of yellow moss, commonly found on grit-stone: I collected, however, what I could of it by brushing the sides of the building, at the distance of three or four feet from the water in the basin: on putting what I had brushed off on a hot iron, I found that it consisted

sifted principally of particles of grist-stone, evidently however mixed with particles of sulphur.

Much of the sulphureous water is used for baths at Harrogate; and for that purpose all the four wells are frequently emptied into large tubs containing many gallons apiece; these constantly stand at the wells, and the casks, in which the water is carried to the several houses, are filled from them. On examining the insides of these tubs, I found them covered, as if painted, with a whitish pellicle. I scraped off a part of this pellicle: it was no longer soluble in water; but, being put on a hot iron, it appeared to consist almost wholly of sulphur. Some of these tubs have been in use many years, and the adhering crust is thick in proportion to the time they have  
1
been

been applied to the purpose; but the sulphur pellicle was sufficiently observable on one which was new in the beginning of this season. The water when it is first put into these tubs is transparent; when it has been exposed to the air for a few hours, it becomes milky; and, where the quantity is large, a white cloud may be seen slowly precipitating itself to the bottom. This white precipitate consists partly, I am not certain that it consists wholly, of sulphur; and the sulphur is as really contained in the waters denominated sulphureous, as iron is contained in certain sorts of chalybeate waters; in the one case the iron is rendered soluble in water by its being united to fixed air, or some other volatile principle; and in the other sulphur is rendered soluble in water by its being united



to fixed air, or some other volatile principle: neither iron nor sulphur are of themselves soluble in water, but each of them, being reduced into the form of a salt by an union with some other substances, becomes soluble in water, and remains dissolved in it, till that other substance either escapes into the air, or becomes combined with some other body.

About forty years ago, they took up the basin of the third well, and a credible person, who was himself present at the operation, informed me, that in all the crevices of the stone on which the basin rested, there were layers of pure yellow sulphur. This I can well believe, for I ordered a piece of shale to be broken off from the bottom of the fourth well; it was split, as shale generally is,

is, into several thin pieces, and was covered with a whitish crust. Being laid on a hot iron, in a dark room, it cracked very much, and exhibited a blue flame and sulphureous smell.

If the water happens to stand a few days in any of the wells, without being disturbed, there is found at the bottom a black sediment; this black sediment also marks the course of the water which flows from the well, and it may be esteemed characteristic of a sulphur water. The surface of the water also, when it is not stirred for some time, is covered with a whitish scum. Doctor *Short* had long ago observed, that both the black sediment, and the white scum, gave clear indications, on a hot iron, of their containing sulphur: I know not whence it has come that his accuracy has been questioned in  
this

this point; certain I am, that on the repetition of his experiments I found them true. The white scum also, which is found sticking on the grass over which the water flows, being gently dried, burns with the flame and smell of sulphur. From what has been said it is clear, that sulphur is found at Harrogate, sticking to the bason into which the water springs; sublimed upon the stones which compose the edifice surrounding the well; adhering to the sides of the tubs in which the water stands; subsiding to the bottom of the channel in which the water runs; and covering the surface of the earth, and of the blades of grass, over which it flows. It is unnecessary to add another word on this subject; it remains that I risk a conjecture or two, on the primary cause of the sulphureous

fulphureous impregnation observable in these waters.

In the Chemical Essay before referred to, I have shewn, that the air separable from the lead ore of Derbyshire, or from Black-Jack, by solution in the acid of vitriol, impregnates common water with the sulphureous smell of Harrogate water; and I have also shewn that the bladder fucus or sea-wrack, by being calcined to a certain point, and put into water, not only gives the water a brackish taste, but communicates to it, without injuring its transparency, the smell, taste, and other properties of Harrogate water. Professor *Bergman* impregnated water with a sulphureous taste and smell, by means of air separated by the vitriolic acid from hepar sulphuris, made by fusion of equal weights of  
sulphur

fulphur and pot-ashes, and from a mass made of three parts of iron filings melted with two of fulphur; and he found also, that Black-Jack and native Siberian iron yielded hepatic air, by solution in acids. This, I believe, is the main of what is known by chemists on this subject; what I have to suggest, relative to the Harrogate waters in particular, may perhaps be of use to future inquirers.

I have been told, that on breaking into an old coal-work, in which a considerable quantity of wood had been left rotting for a long time, there issued out a great quantity of water smelling like Harrogate water, and leaving, as that water does, a white scum on the earth over which it passed. On opening a well of common water, in which there was  
found



found a log of rotten wood, an observant physician assured me, that he had perceived a strong and distinct smell of Harrogate water. Dr. *Darwin*, in his ingenious Account of an artificial Spring of Water, published in the first part of the LXXVth volume of the Philosophical Transactions, mentions his having perceived a slight sulphureous smell and taste in the water of a well which had been sunk in a black, loose, moist earth, which appeared to have been very lately a morass, but which is now covered with houses built upon piles. In the bog or morass above-mentioned there is great plenty of sulphureous water, which seems to spring from the earth of the rotten wood of which that bog consists. These facts are not sufficient to make us certain,

that rotten wood is efficacious in impregnating water with a sulphureous smell ; because there are many bogs in every part of the world, in which no sulphureous water has ever been discovered. Nor, on the other hand, are they to be rejected as of no use in the inquiry ; because wood, at a particular period of its putrefaction, or when situated at a particular depth, or when incumbent on a soil of a particular kind, may give an impregnation to water, which the same wood, under different circumstances, would not give.

The bilge water, usually found at the bottom of ships which are foul, is said to smell like Harrogate water : I at first supposed, that it had acquired this smell in consequence of becoming putrid in contact with  
the

the timber on which it rested, and this circumstance I considered as a notable support to the conjecture I had formed of rotten wood being, under certain circumstances, instrumental in generating the smell of Harrogate water. But this notion is not well founded; for the bilge water is, I suppose, salt water; and Dr. *Short* says, that sea water, which had been kept in a stone bottle six weeks “stunk not much short of Harrogate sulphur water.” It has been remarked above, that calcined sea-wrack, which contains a great deal of sea salt, exhales an odour similar in all respects to that of Harrogate water; and in confirmation of the truth of this remark, I find that an author, quoted by Dr. *Short*, says, that “Bay salt thrice calcined, dissolved in water, gives exactly the

odour of the sulphur Well at Harrogate." From these experiments considered together, it may, perhaps, be inferred, that common salt communicates a sulphureous smell to water both by putrefaction and calcination. Hence some may think, that there is some probability in the supposition, that either a calcined stratum of common salt, or a putrescent salt spring, may contribute to the production of the sulphureous smell of Harrogate water ; especially as these waters are largely impregnated with common salt. However, as neither the salt in sea water, nor that of calcined sea-wrack, nor calcined bay salt, are any of them absolutely free from the admixture of bodies containing the vitriolic acid, a doubt still remains, whether the sulphureous exhalation, here spoken

spoken of, can be generated from substances in which the vitriolic acid does not exist.

The shale from which alum is made, when it is first dug out of the earth, gives no impregnation to water; but by exposure to air and moisture its principles are loosened, it shivers into pieces, and finally moulders into a kind of clay, which has an aluminous taste. Alum is an earthy salt resulting from an union of the acid of sulphur with pure clay; and hence we are sure, that shale, when decomposed by the air, contains the acid of sulphur; and from its oily black appearance, and especially from its being inflammable, we are equally certain that it contains phlogiston, the other constituent part of sulphur. And indeed pyritous substances, or combinations



of sulphur and iron, enter into the composition of many, probably of all sorts of shale, though the particles of the pyrites may not be large enough to be seen in some of them; and if this be admitted, then we need be at no loss to account for the bits of sulphur, which are sublimed to the top of the heaps of shale, when they calcine large quantities of it for the purpose of making alum: nor need we have any difficulty in admitting, that a phlogistic vapour must be discharged from shale, when it is decomposed by the air. Dr. *Short* says, that he burned a piece of aluminous shale for half an hour in an open fire; he then powdered and infused it in common water, and the water sent forth a most intolerable sulphureous smell, the very same with Harrogate water. He burned  
several

several other pieces of shale, but none of them stunk so strong as the first. This difference may be attributed, either to the different qualities of the different pieces of shale which he tried, or to the calcination of the first being pushed to a certain definite degree; for the combination of the principles on which the smell depends may be produced by one degree of heat, and destroyed by another. I have mentioned, briefly, these properties of shale, because there is a stratum of shale extended over all the country in the neighbourhood of Harrogate; several beds of it may be seen in the stone quarry above the sulphur wells; many of the brooks about Harrogate run upon shale, and the sulphur wells spring out of it. They have bored to the depth of twenty yards into

this shale, in different places, in search of coal, but have never penetrated through it. Its hardness is not the same at all depths. Some of it will strike fire, as a pyrites does, with steel; and other beds of it are soft, as if in a state of decomposition, and the sulphur water is thought to rise out of that shale which is in the softest state. But whatever impregnation shale when calcined, or otherwise decomposed to a particular degree, may give to the water which passes over it, it must not be concluded, that shale in general gives water a sulphureous impregnation; since there are many springs, in various parts of England, arising out of shale, in which no such impregnation is observed.

I forgot to mention, in its proper place, that having visited the bog,  
 so

so often spoken of, after a long series of very dry weather, I found its surface, where there was no grass, quite candied over with a yellowish crust, of tolerable consistency, which had a strong aluminous taste, and the smell of honey. *Bergman* speaks of a turf found at Helsingberg in Scania, consisting of the roots of vegetables, which was often covered with a pyritous cuticle, which, when elixated, yielded alum; and I make no doubt, that the Harrogate morass is of the same kind.

Whether nature uses any of the methods which I have mentioned of producing the air by which sulphureous waters are impregnated, may be much questioned; it is of use, however, to record the experiments by which her productions may be imitated; for though the line of  
human

human understanding will never fathom the depths of divine wisdom, displayed in the formation of this little globe which we inhabit; yet the impulse of attempting an investigation of the works of God is irresistible; and every physical truth which we discover, every little approach which we make towards a comprehension of the mode of his operation, gives to a mind of any piety the most pure and sublime satisfaction.

ESSAY



## E S S A Y II.

*Experiments and Observations on various Phænomena attending the Solution of Salts.*

HAVING lately had occasion, in some chemical inquiries, to make various solutions of salts, I met with some phænomena, which did not appear to me either to have been sufficiently attended to, or consistently explained by writers upon that subject. The suspension of salts in water, of metals in acids, of sulphur in oils, and of other bodies in menstrooms specifically lighter than the bodies themselves, hath  
 ever

ever been considered in chemistry, as a problem of difficult solution. Those philosophers who acquiesce, upon the whole, in the cause which hath been assigned for this phænomenon by Sir Isaac Newton, in his optical Questions, have taken great pains to illustrate the manner how it is effected, by supposing that the bodies are received into the pores of their respective menstruums, and there kept suspended by the attraction or, as Bernouilli and Freind would have it, by the resistance arising from the tenacity of the fluid. Hence it happens, say these philosophers, that after water is saturated with one salt, it is still capable of dissolving somewhat of a second kind, and being saturated with that, of a third, and so on; just as a vessel filled as full as possible with spheres

or

or cylinders of one magnitude hath a capability of receiving similar bodies of an inferior size, or bodies of a different figure. The opinion of Gassendus seems to have been generally adopted; he endeavours to prove, from the experiment which hath been mentioned, not only the porosity of water, but a diversity in the figures of the pores: *Affero & aliud experimentum singulare, quo visus sum mihi deprehendere interspersa hujusmodi spatiola inania intra aquam dari.*—*Aiebam, cum sint salis corpuscula cubica, poterunt ea quidem replere spatiola, quæ & ipsa cubica fuerint; at cum non modo commune sal, sed alumen etiam, quod est octahedricum, halinitrum item, & sal ammoniacum saccharumque & alia quæ aliarum sunt figurarum eâdem aquâ exsolvi possunt; erunt ergo etiam in*  
*aqua*

*aqua spatiola octaedrica atque id genus alia; adeo ut aqua, tametsi sale saturata fuerit, nihilominus & alumen et cetera omnia exsolvere possit ac in sese transfundere.* Gas. Phys. l. i. sect. 1. cap. iii. The reason why warm water dissolves in general more salt than cold water, seems as if it might be derived from the same principle, was it true; the interstices between the elementary particles of water are enlarged by the expansion of the fluid, and might therefore be supposed capable of admitting into them a larger quantity of salt. This doctrine hath been embraced by most philosophers, especially by the late Abbé Nollet, in the 4th volume of his *Leçons de Physique*; and I do not know that it hath been opposed by any body. The late Mr. Eller, of Berlin, hath carried this speculation

speculation so far, as to publish a Table in the Berlin Memoirs for 1750, exhibiting the several quantities of above twenty different kinds of salt, which a given quantity of water will absorb into its pores, without being in the least augmented in bulk. It is not therefore without some uneasiness that I find myself constrained to dissent from the general opinion, and particularly to differ from Mr. Eller, who hath treated this subject *ex professo*; who made his experiments, as he himself assures us, with the greatest exactness; and who was led by them to the discovery of what he is pleased to call, *une verité incontestable, savoir, que les plus petites parties constituantes de l'eau sont doüees de pores ou d'interstices dans lesquels les atomes de sel peuvent nicher, sans augmenter*



*leur volume.* I do not at present see any very probable method of reconciling the different results of our inquiries; I will therefore content myself with giving a plain relation of the experiments which I have made upon this subject.

#### EXPERIMENT I.

I took a large mattrafs, containing, when filled to the middle of its neck, 132 ounces of water, Troy weight; the diameter of the cavity of the neck was six lines: having with a diamond marked the place where the water stood in the neck of the mattrafs, I dropped into it a single piece of purified nitre, the weight of which was a 2600th part of the weight of the water, and immediately observed that the water was considerably elevated in the tube:  
during

during the solution of salt, the water sunk near one third of its whole elevation; but when the solution was entirely finished, it remained very sensibly raised above the mark: so that, even from the experiment with this instrument, we may be assured that water cannot absorb  $\frac{1}{2000}$ th part of its weight of nitre, without being augmented in bulk. Mr. Eller, from his experiments, concludes, that eight ounces of water will absorb one drachm and a half, or above a 42d part of its weight of nitre; and hence I supposed the quantity of water which I used would have absorbed above sixteen times as much, or above three ounces; whereas the event shewed that it could not absorb  $\frac{1}{20}$  of an ounce. From the sinking of the water during the solution, I was at

first inclined to believe that some part at least of the nitre was taken into the pores of the water: in order to see whether this conjecture could be verified by fact, I made the following experiment.

#### EXPERIMENT II.

I chose two matrasses of unequal sizes, containing quantities of water in the proportion of 12 to 1, the diameters of the necks being equal: into the largest I put  $\frac{1}{650}$ th part of the water's weight of nitre, and an equal quantity into the smaller; and I observed that the water, as well before as after the solution, was equally elevated in them both: this experiment was repeated. Now, if a given quantity of water can absorb into its pores, without being increased in magnitude, any quantity of salt however small, it seems reasonable

senable to suppose that a quantity containing twelve times as many pores should absorb twelve times as much, (since it is an allowed fact that the minutest portion of a salt is uniformly diffused through the largest quantity of water) and it might consequently be expected, that the water should rise higher in the neck of the smaller matrafs than in that of the larger, which is contrary to the experiment.

#### EXPERIMENT III.

Apprehending that common pump water, with which I had made the preceding experiments, might have its interstices preoccupied by selenites and other heterogeneous matters, and be thereby rendered incapable of admitting into them any additional substance; and observing that Mr. Eller had used in all his expe-

riments 8 ounces of distilled water, I had hopes to have reconciled my experiments to his by that means: but upon trial, with distilled water, I found the elevation precisely the same as before. Nor do the conclusions depend upon the kind of salt; they hold true *mutatis mutandis* of any other salt as well as nitre. During the solution the water is refrigerated and thereby contracted in magnitude, and the smaller the quantity the greater will be the cold and consequent contraction produced by the addition of small portions of salt; but I cannot suppose that this circumstance could be overlooked by Mr. Eller, though it induced me to use a much larger quantity, or that he attributed the sinking of the water during the solution, to an imbibition of the particles of the

the



the several salts into the pores of the water, and thence by calculation constructed his table.

#### EXPERIMENT IV.

Having always remarked that the water in the neck of the matrafs was elevated higher upon the first immersion of the salt, than after it was wholly dissolved, I endeavoured to ascertain the difference in several kinds of salt. To do this with the greater exactness, I pitched upon a matrafs which had a neck as far as I wanted it accurately cylindrical, as I found by observing the elevations occasioned by the additions of equal portions of water; the matrafs held about 67 ounces of water. The salts I used were all dry, and in as large pieces as the neck of the matrafs would admit; the water was heated to the forty-second

degree of Fahrenheit's thermometer, and kept as nearly as could be in that temperature. I changed the water for each experiment, and used in each 24 penny weights of salt; the heights to which the water rose, as measured from a mark in the middle of the tube, before and after the solution of each salt, are expressed in the following table: the first column denotes the height to which the water was elevated by 24 penny weights of salt before its solution, the second after its solution, the third the difference in fractional parts of the elevation before solution.

Elevation by 24 penny

weights of simple water 0 58

24 penny weights of ge-

nuine Glauber's salt 42 36  $\frac{2}{7}$

Vol. salt of sal. ammon. 40 33  $\frac{7}{40}$

Sal

Sal ammon.	40	39	$\frac{1}{46}$
Refined white sugar	39	36	$\frac{1}{13}$
Coarse brown sugar	39	36	$\frac{1}{13}$
White sugar candy	37	36	$\frac{1}{37}$
Glauber's salt from Lym- ington	35	29	$\frac{6}{35}$
Terra foliata tar.	37	30	$\frac{7}{37}$
Rochelle salt	33	28	$\frac{5}{33}$
Alum not quite dissolved	33	28	$\frac{5}{33}$
Borax not half dissolved in 2 days	33	31	$\frac{2}{33}$
Green vitriol	32	26	$\frac{3}{16}$
White vitriol	30	24	$\frac{1}{5}$
Nitre	30	21	$\frac{3}{10}$
Sal gem. from Norwich	27	17	$\frac{10}{27}$
Blue vitriol	26	20	$\frac{3}{13}$
Pearl ash	25	10	$\frac{3}{5}$
Vitriolated tartar	22	11	$\frac{1}{2}$
Green vitriol calcined to whiteness	22	11	$\frac{1}{2}$
Dry salt of tartar	21	13	$\frac{8}{21}$
Basket sea salt	19	15	$\frac{4}{19}$

Corrosive sublimate	14	10	$\frac{2}{7}$
Turbith mineral	9	0	

Had I not been in some measure persuaded, from the result of the preceding experiments, that no portion of any salt could be absorbed into the pores of water, I should have readily concluded that the third column of this table denoted such parts of 24 penny weights of the several salts as might be lodged in the interstices of 67 ounces of water, without increasing its magnitude: the quantities indeed which might have been thus ascertained would have but ill agreed with those which are determined by Mr. Eller; and that diversity of quantity may suggest a doubt concerning the validity of his principle. The sinking of the water in the neck of the matrafs

seems

seems to be a general phænomenon attending the solution of all salts; the quantity of the descent is various from  $\frac{1}{40}$  to  $\frac{1}{2}$  of the whole elevation in those salts which I have tried. In forming the table, I repeated many of the experiments, but found no variation which could affect the general conclusion; with particular attention I repeated the solution of vitriolated tartar, for I thought it a very remarkable circumstance that one of the hardest salts should be more diminished in proportion to its whole bulk than any other, but the numbers in the table 22 and 11 accurately expressed the height before and after solution upon the repetition of the experiment, so that it may be relied upon as a certain fact that a cubic inch of vitriolated tartar is by solution in

water



water reduced to half a cubic inch, though the water cannot, as appeared from an experiment I made, absorb  $\frac{1}{1000}$ th part, nor, as I believe, any part, of that salt without being augmented in magnitude. It is evident from the table that *sal gemmæ*, blue vitriol, corrosive sublimate, calcined vitriol, and in general those salts which retain the least water in their composition and constitute the hardest masses, sink more in proportion to their respective bulks than any other. I own myself at a loss for a general principle to explain this general phænomenon, unless the air contained in the several salts may be esteemed sufficient for the purpose; a very copious separation of air from the salts during the whole time of their solution may be readily observed in all of them, and a small  
 portion

portion of it, combined with the particles of a salt, may augment its bulk, without sensibly increasing its weight. Yet the two following experiments rather tend to diminish the probability of this opinion.

#### EXPERIMENT V.

I took water which had been well purged from its air by long boiling, and which had been corked up whilst it was warm; when it had acquired a proper temperature, I filled a matrafs with it, as before, and putting into it *sal gemmæ*, &c. I observed that the elevation before solution was the same as when common water was used, and that it sunk equally in the neck during the solution; but then the separation of air seemed greatly less in all the trials I made. This phænomenon is easily explained:  
common

common water is always faturated with air; upon the addition of any falt, the particles of water begin to attract and diffolve the falt, and let go the air with which they are united; this air, added to the air contained in the falt, renders the whole much more vifible in common than in boiled water. Muffchenbrook and others are of opinion, that air only fills the interftices of water, without augmenting its bulk; they ground their opinion upon observing that the fpecific gravities of common water and of water purged from its air are equal; the fact, taking it for granted, will fcarcely authorize the conclufion: for, fuppoſing that a cubic inch of common water contains even a cubic inch of air, the difference of the weight of the water when faturated with air, and when freed

freed as much as possible from it (though probably it can never be wholly freed from it), will not equal  $\frac{1}{4}$  of a grain: how imperceptible then must the difference be, if water, instead of an equal bulk, doth not contain  $\frac{1}{1000}$ th part of its bulk of air, which is a supposition much nearer to the truth: the air is separated from the water during the solution of the salt, and the particles of the salt probably occupy its place as happens in other chemical precipitations; but we cannot thence infer that they are received into the interstices of the water, unless we had more conclusive arguments, to prove that the air itself was lodged in them. I varied the preceding experiment by putting two equal and transparent pieces of sal gemmæ into two tall drinking glasses, filled one with common, the  
other

other with boiled water; from the first there continually ascended a very visible stream of air, and the salt and the bottom of the glass were covered with bubbles, it seeming as if the water quitted its air to dissolve the salt; in the other, though some air was seen breaking out from the salt whilst it was dissolving, there did not seem to be any precipitated, as it were, from the water. In most of the experiments which I made, the boiled water dissolved a given quantity of salt sooner than the common water, when they had the same degree of heat; but the difference in time might be owing to the different magnitude of the surfaces of the salt, though from the generality of the event, I should rather attribute it to the different dissolving powers of

I

water,



water, when replete with, and when deprived of air.

#### EXPERIMENT VI.

Thinking that the difference in the bulks of the water before and after solution might be owing to the separation and escape of some volatile principle; I took care to balance as accurately as I could, water and sal gemmæ, water and salt of tartar, water and vitriolated tartar, &c. and then putting the several salts into the water, I observed when the solution was accomplished, whether the equilibrium of the scales was affected, but I could not distinguish any change. Dr. Hales and others have spoken of the existence of air in salts, and have in two or three instances investigated the quantity, but after a very different manner  
from

from that I have used ; nor can I think myself at liberty to esteem this air which is separated by solution, of the same nature with that which is called by him and others fixed air, inasmuch as fixed air makes a considerable part of the weight of the bodies from which it is extracted, precipitates lime water, and is seldom discharged (or perhaps produced from some of the minute parts of the body being converted by the violence of the fire, &c. into an elastic fluid), except when the body is decomposed ; whereas this makes only a considerable part of the bulk of bodies, and thus diminishes their specific gravity without sensibly increasing their absolute weight ; does not, as I collected from some rough trials, render lime water turbid ; and is set at liberty, though not by a

mechanical division, yet by an operation somewhat different from chemical decomposition. It hath been remarked by some, that saline solutions will not crystallize without much difficulty in an exhausted receiver; perhaps because the particles of salt cannot attract that principle which should cement them together, which at least may be seen escaping from them when they begin to be separated. Mr. Boyle observed, that aquafortis, poured upon a strong vegetable alkali, did not crystallize till it had been long exposed to the air (though I should rather attribute this failure to the weakness of his aquafortis than to the want of air, since I have frequently, by using the fuming spirit of nitre, obtained crystals of an inch in length almost instantaneously);

and several other phænomena might be adduced respecting the crySTALLIZATION of salts, which seem to indicate the necessity of admitting air as a very efficacious instrument in producing that effect: but future experience may tend to elucidate this matter. Having used great attention in making the experiments from which the preceding table was composed; I thought I had a good opportunity of deriving from it the specific gravities of the salts which are there mentioned. I accordingly calculated the following table; in the first column of which are expressed the specific gravities as calculated from the increase of bulk before solution; in the second, after the solution.

Genuine Glauber's salt	1,380	1,611
Crytals of kelp	1,414	1,467
		Volat.

Volat. falt of fal am-		
moniac	1,450	1,787
Sal ammoniac	1,450	1,487
Sugar refined, brown,		
barley	1,487	1,611
White sugar candy	1,567	1,611
Terra foliata tartari	1,567	1,933
Glauber's falt from		
Lymington	1,657	2,000
Rochelle falt	1,757	2,071
Alum	1,757	2,071
Borax	1,757	
Green vitriol	1,812	2,230
White vitriol	1,933	2,416
Nitre	1,933	2,766
Very transparent fal		
gem. from Northwich	2,143	3,411
Blue vitriol purified	2,230	2,900
Pearl afh	2,320	5,800
Vitriolated tartar	2,636	5,272
Green vitriol calcined		
to whitenefs	2,636	5,272



Dry falt of tartar	2,761	4,461
Basket fea falt	3,052	3,866
Corrofive fublimatè	4,142	5,800
Mercury diftilled with acid of vitriol, and freed from its acid by a ftrong fire	6,444	

The numbers in the firft column correfpond very well, upon the whole, with the fpecific gravities which have been determined by others hydroftatically; thus the fpecific gravities of nitre, alum, white and green vitriol, fal ammoniac, fal gemmæ, &c. are greater than what are affigned to thefe bodies by fome authors, and lefs than what have been determined by others; it feems as if the fpecific gravities of faline bodies might, in a proper vefſel, be more accurately afcertained from the  
observed

observed increase of the water's bulk than any other way. Upon the supposition that the escape of the air is the reason of the water's sinking during the solution, and that this air contributes little to the weight of the salts, though it may be absolutely necessary to the exhibiting the saline moleculæ under a visible crystalline appearance; the second column will denote the real specific gravities of the salts as freed from air. That this air is combined with the salts, and doth not simply adhere to their surfaces, may appear from hence, that the specific gravities, as calculated from the increase of bulk observed in the water before solution, sufficiently correspond with those which philosophers have determined hydrostatically: nor indeed, upon exhausting the air from

the salts, by an air pump, could I observe that it was separated, in less quantity during solution.

#### EXPERIMENT VII.

Since equal quantities of salt must contain equal quantities of air, it might be expected *a priori*, if the escape of the air was the occasion of the water's sinking, that equal weights of salt would produce equal augmentations of bulk, and unequal weights augmentations proportionable to their weights; but, to be assured of this, I took a matrafs containing about 30 ounces of water, the tube being cylindrical for about 7 inches in length. When the matrafs was filled to a proper mark, I put into it 7 pennyweights of powdered sal gem.: the water after the solution had risen through 17 tenths  
of

of an inch; by the addition of 14 pennyweights more, the water was raised through 51 divisions from the first mark, or twice 17 from where it stood after the solution of 7 pennyweights. In the same matrafs I tried a similar experiment with nitre; the water was raised through 10 divisions, by 3 pennyweights of powdered nitre; and by 18 more, it stood after the solution at the 70th division from the first mark, and consequently rose through six times the space, through which it had been raised by 3 pennyweights. From these, and other experiments of the same kind, I am disposed to believe that equal portions of salt produce equal augmentations in the bulk of the water wherein they are dissolved; at least, this holds true when the salt dissolved bears but a small propor-

tion to what would be requisite to saturate the water. But, in making this experiment, great care must be taken to keep the salts of the same dryness; I had once tried it with three equal quantities of sea salt, and arrived at a quite different conclusion; the increases of bulk occasioned by the solution of the several salts being separately taken, as 15, 16, 17, but the salt being much drier than the air in the laboratory, had undoubtedly attracted the humidity, and that portion had attracted the most which had been the longest in it, and which was last dissolved. Nor should the temperature of the water be neglected; a sensible error may proceed from a minute change in that. This experiment confirms the first, for, was any part of salt absorbed into the pores of the water, it



it certainly ought to be expected that the elevation occasioned by the solution of 3 pennyweights of nitre should be less than  $\frac{1}{6}$ th of that occasioned by 18 pennyweights, and yet I found it to be accurately  $\frac{1}{6}$ th upon repeating the experiment with distilled water. It confirms it too in another view, 3 pennyweights or  $\frac{1}{250}$ th part of the weight of the water, raised it through one inch; hence  $\frac{1}{250}$ th part would have raised it through one tenth of an inch, which any eye may distinguish.

Dr. Lewis, for whose great abilities in chemistry I have a very high respect, in his little treatise upon American potashes, is of opinion, that the augmentation of the bulk of water doth not proceed uniformly, according to the quantity of salt added; and he forms his conclusion  
from

from observing, that the losses of weight sustained by the same body in different solutions, were not uniform, but continually diminished; the losses corresponding to seven successive equal quantities being as  $24\frac{1}{2}$ . 24.  $23\frac{1}{2}$ . 22. 22. 21. 20. Upon considering this matter in a mathematical light, I am inclined to draw a quite different conclusion; but I will first mention some experiments which I had formerly made with a different view, and which agree very well with Dr. Lewis's.

#### EXPERIMENT VIII.

I had conceived that if, in a given quantity of water, several quantities of salt, increasing in any arithmetical or geometrical progression, were dissolved; that the increments of specific gravity would increase in the same

same progression. In order to see whether this conjecture could be established by experiment, I dissolved in a given quantity of water, different portions of sea salt, increasing in the progressions expressed in the annexed tables, where the first column of each denotes the proportional quantities of salt in pennyweights; the second, the loss of weight of a given body in quarter grains; the third, the excess of the specific gravity of each solution, above the specific gravity of water.

TAB. I.

	263	0
9	273	10
18	282	19
27	292	29
36	301	38
45	309	46

TAB. II.

	263	0
5	269	6
10	274	11
15	280	17
20	285	22
25	289	26
30	294	31
35	300	37
40	304	41
45	309	46
50	312	49
55	316	53

TAB. III.

	883	0
4	899	16
8	915	32
12	930	47
16	945	62
20	959	76
24	971	88
28	985	102
32	996	113
36	1009	126
40	1020	137

The

The difference of the numbers in the third column of each table from arithmetical progressions, is obvious at first view, the difference of the two last numbers of each being considerably less than the difference between the two first: and the numbers 6. 11. 22. 41. corresponding to the geometrical progression 5. 10. 20. 40. in the second table as well as the numbers 16. 32. 62. 113 corresponding to the geometrical progression 4. 8. 16. 32, in the third, differ considerably from geometrical progressions, whose common ratio is  $\frac{1}{2}$ .

In making these experiments there are three obvious sources of error: the heat may not remain constant; the additional weights of salt may not be accurately equal; and the weight of the given body may be  
more

more or less than what is expressed by any quantity less than  $\frac{1}{4}$  of a grain; yet the differences of the preceding numbers, from arithmetical or geometrical progressions, are too great to be explained from any or all of these sources taken together. We may observe that the losses of weight, corresponding to equal portions of salt, are, upon the whole, diminished; but it will not follow from thence that the bulks are not equally augmented. For, since the specific gravity of every body is properly denoted by a fraction, whose numerator expresses the absolute weight, and denominator the magnitude of the body; let  $\frac{w}{m}, \frac{w+x}{m+y}, \frac{w+2x}{m+z}, \frac{w+3x}{m+s}, \&c.$  be a series of fractions, whose several numerators express the weights of a given



given quantity of water, as increased by the addition of equal portions of any salt denoted by  $x$ , and whose denominators express the bulks of the water after the solution of each portion of salt, the increments of bulk being denoted by  $y, z, s$ ; now let us suppose that the losses of weight sustained by the same body, that is, the specific gravities, increase uniformly, then will the above series of fractions increase uniformly,

$$\text{let } \frac{w}{m} = a; \frac{w+x}{m+y} = a+b; \frac{w+2x}{m+z} = a+2b;$$

$$\frac{w+3x}{m+s} = a+3b, \text{ from these equations}$$

investigating the proportion between  $y, z, s$ , which represent the augmentations of bulk, it will appear that  $y : z :: a+2b : 2a+2b$ , or in a greater ratio than that of  $1 : 2$  and that  $z : s :: 2a+6b : 3a+6b$ , or in a greater ratio than that of  $2 : 3$ , in which

which ratios they ought respectively to have been, had the denominators or the bulks of the fluid increased uniformly, when the specific gravities or absolute weights increased uniformly. We see from this, what conclusion should have been formed, had the increments of specific gravity from equal portions of salt been equal. Again, suppose that

$\frac{w}{m}, \frac{w+p}{m+q}, \frac{w+2p}{m+2q}, \frac{w+3p}{m+3q},$  &c. denote a

series of fractions, whose numerators, expressing the weights of a given quantity of water as increased by the addition of salt, and whose denominators, expressing the bulks, both increase uniformly, then will the several differences between the 2d and 1st, between the 3d and 2d,

and so on, be as  $\frac{1}{m \times m+q}, \frac{1}{m+q \times m+2q},$   
 $\frac{1}{m+2q \times m+3q}, \frac{1}{m+3q \times m+4q},$  &c. which

fractions

fractions being inverfely as their denominators constitute a decreasing series; but the increments of specific gravity from the addition of equal portions of falt, are proportionable to thefe fractions, and therefore ought perpetually to decrease, though we allowed the bulk of the compound to be precisely equal to the bulk of the water and falt taken together, that is, though we allowed the bulk of the water to increase uniformly according to the quantity of falt added: now as it is evident from Dr. Lewis's experiments, and from each of the preceding tables, that the increments of specific gravity do decrease upon the whole, when the absolute weights increase uniformly, we may venture to conclude that the bulks increase uniformly alfo. I thought proper

to explain the foregoing principle and to determine the ratio, because the matter seems to have been mistaken by many; however, it may be easily apprehended that the increments of specific gravity, from the addition of equal quantities of salt to a given weight of water, ought perpetually to decrease; because the difference between the specific gravities of the water and of the salt perpetually decreases, as the water approaches to perfect saturation. In like manner, if to a given quantity of water we add any number of equal quantities of oil of vitriol, or any fluid miscible with and heavier than water; the increments of specific gravity will perpetually decrease, though they will never entirely vanish, because there is a perpetual approximation to the specific

gravity of the acid, which yet the mixture can never acquire; and, *vice versa*, if to water we add a lighter fluid, as spirits of wine by equal portions, the specific gravity of the mixture will constantly decrease by unequal decrements; but the decrements will never vanish, because the mixture must ever remain specifically heavier than spirit of wine.

#### EXPERIMENT IX.

The quantities of various salts, which may be dissolved in a given quantity of water, have been ascertained by Boerhaave, Eller, Spielman, and others; their accounts differ somewhat from one another, as might be expected from the different temperatures of the air, the different state of their salts, the different



ferent times (a circumstance of no small consideration in this matter) which they allowed the water to act upon the salts before they concluded it to be fully saturated, and from some other circumstances which might perhaps with advantage be taken into the account, and a more accurate table composed than hath hitherto been published; but as the differences would be small, and might not tend to any new discoveries, I could not persuade myself to be at the trouble of making the requisite experiments. I thought it would be a more useful undertaking to determine the specific gravities of saturated solutions of various salts. In composing the following table, I used every possible precaution; the solutions were fully saturated, by permitting the water to

rest upon the salts for some weeks, and frequently shaking the solutions during the interval: I had some reasons for choosing this method rather than the much shorter one of dissolving the salts in hot water, and letting the solutions cool, though the event will be much the same in both ways; my balance was extremely sensible, though I did not use any weight less than a quarter of a grain; the water in which the salts were dissolved was not  $\frac{1}{4}$  of a grain in 890 heavier than distilled water; the solutions were all of the same temperature, Fahrenheit's thermometer standing between 41 and 42° during the whole time of taking the specific gravities.

A Table exhibiting the specific gravities of water saturated with  
various

various falts. Thermometer 41  
—42°, barometer 30 inches.

Water in which the falts were

diffolved	1,000
Saturated with quicklime	1,001
Cryftals of tar	1,001
Arfenic	1,005
Borax	1,010
Corrof. fublim.	1,037
Alum	1,033
Genuine Glauber's falt	1,052
Vitriolated tart.	1,054
Common falt	1,198
Arfen. nitre	1,184
Glau. falt Lyming.	1,232
Sal ammon.	1,072
Vol. falt of fal am.	1,077
Cryftals of kelp	1,087
Nitre purified	1,095
Rochelle falt	1,114
Blue vitriol	1,150
	Green

Green vitriol	1,157
Sal gemmæ	1,170
Epsom salt Lym.	1,218
White vitriol	1,386
Pearl ash	1,534

By making other tables similar to the preceding, when the thermometer stands at  $62^{\circ}$ ,  $82^{\circ}$ ,  $102^{\circ}$ , &c. or when the heat increases or decreases in any known ratio; it is extremely probable that the law, according to which the dissolving power of water varies with the variation of its heat, might be investigated. I have some reasons for thinking that though it increases with the increase of heat, yet it doth not increase in the direct simple ratio of the heat; but what the law is, or whether all salts follow the same law, I cannot, from any experiments I have already made,

made, determine; and I have no leisure at present to prosecute the inquiry. The conclusion will be unavoidably liable to a small inaccuracy; for whether the specific gravities be investigated by weighing the several fluids in a given vessel filled to a given mark, or by weighing a given solid in each of them, we shall not thence obtain the weights of equal bulks, since the containing vessel or the solid, from the difference of the heats, have a different capacity or a different bulk. However, it is not apprehended that this circumstance would sensibly affect the conclusion, especially as it is subject to calculation and might be allowed for. It ought, at the same time, to be observed, that a given bulk of the water with which the specific gravities are composed,



will have different weights when the heats are different; and these differences ought first to be ascertained.

#### EXPERIMENT X.

Having thus determined the specific gravities of saturated solutions of several salts, in a given degree of heat; my next inquiry was to find the specific gravities of water impregnated with a given quantity of the several salts: I accordingly dissolved in 168 pennyweights of water, 14 pennyweights, or  $\frac{1}{12}$  of the weight of the water of the eight following salts. The thermometer was at  $40^{\circ}$  and barometer at  $29\frac{1}{2}$ .

A Table of the specific gravities of water impregnated with  $\frac{1}{12}$  of its weight of

Water	1,000
Sea salt	1,059
	Blue

Blue vitriol	1,052
Nitre	1,050
White vitriol	1,045
Green vitriol	1,043
Glau. salts Lym.	1,039
Glau. salts Genu.	1,029
Sal ammon.	1,026

I could not have made this table much more extensive, since in the 40th degree of the thermom. water will not dissolve  $\frac{1}{12}$  of its weight of alum, borax, vitriolated tartar, corrosive sublimate, and a great many other salts; however, as such a table cannot fail of being useful in chemical, and perhaps medical researches, it would be worth while to make it more general, either by dissolving a less portion of salt, or making use of a greater degree of heat.

## EXPERIMENT XI.

To these tables I have subjoined another of a different nature, wherein the specific gravities of water impregnated with different quantities of the same salt from  $\frac{1}{3}$  down to the 1024th part of the weight of the water, are determined. I cannot accuse myself of carelessness in making any of the experiments from which the table is formed; but part of it being made in a room where the heat was about  $55^{\circ}$ , and the other in my laboratory, when it did not exceed  $46^{\circ}$ , a certain inaccuracy, though it will be a very small one, and scarce sensible in the weight of the small body which I used, will attend it upon that account. The salt was sea salt of the finest kind,  
and

and extremely dry; many of the experiments were repeated.

A Table of the specific gravity of water impregnated with different quantities of sea salt. Thermometer between 46 and 55°.

Water	1,000
Salt $\frac{1}{3}$	1,206
$\frac{1}{4}$	1,160
$\frac{1}{5}$	1,121
$\frac{1}{6}$	1,107
$\frac{1}{7}$	1,096
$\frac{1}{8}$	1,087
$\frac{1}{9}$	1,074
$\frac{1}{12}$	1,059
$\frac{1}{14}$	1,050
$\frac{1}{15}$	1,048
$\frac{1}{16}$	1,045
$\frac{1}{18}$	1,040
$\frac{1}{21}$	1,032
$\frac{1}{24}$	1,029

( 92 )

$\frac{1}{27}$	1,027
$\frac{1}{28}$	1,025
$\frac{1}{30}$	1,024
$\frac{1}{32}$	1,023
$\frac{1}{36}$	1,020
$\frac{1}{39}$	1,019
$\frac{1}{42}$	1,015
$\frac{1}{48}$	1,014
$\frac{1}{54}$	1,013
$\frac{1}{55}$	1,012
$\frac{1}{72}$	1,009
$\frac{1}{84}$	1,007
$\frac{1}{108}$	1,006
$\frac{1}{126}$	1,005
$\frac{1}{144}$	1,004
$\frac{1}{162}$	1,003
$\frac{1}{192}$	1,0029
$\frac{1}{256}$	1,0023
$\frac{1}{320}$	1,0018
$\frac{1}{448}$	1,0017
$\frac{1}{512}$	1,0014



$$\frac{1}{848} \quad 1,0008$$

$$\frac{1}{1024} \quad 1,0006$$

From this table it will be easy to determine how much the specific gravity of water is increased by the solution of a given quantity of salt, and, *vice versa*, if we know the specific gravity of any solution of salt, we may form a good conjecture of the quantity of salt contained in it, which observation may be of ready use in estimating the strength of brine springs, and of sea water, taken up in different climates, or upon different coasts in the same climate. Thus, if a salt spring, or sea water, should weigh  $\frac{1}{36}$  more, bulk for bulk, than common water; we may conclude that it contains  $\frac{1}{36}$  of its weight of salt; if  $\frac{1}{40}$ , it hath nearly  $\frac{1}{28}$ ; if  $\frac{1}{25}$ ,  $\frac{1}{18}$ ; if  $\frac{1}{20}$ ,  $\frac{1}{14}$ ; and so on: we may always find limits

limits near enough to form a conclusion from, though the exact number denoting the weight in any particular case should not be met with in the table.

After I had drawn up the preceding account of the experiments which I had made, I received the Berlin Memoirs for 1762, published last year, in which there is a memoir entitled---*Experiences sur le poids du sel et la gravité spécifique des saumures faites et analysées, par M. Lambert*. In this memoir, the very ingenious author hath made much use of the principle, which I have endeavoured to call in question in the beginning of this paper; and hath calculated the different quantities of sea salt, which are absorbed into the pores of water, when a given quantity is dissolved in different

ferent quantities of water. The admission of this principle hath drawn him into some conclusions which seem not quite consonant to true philosophy; as when he asserts that the quantity which is absorbed into the pores, is not proportional to the number of the pores or the quantity of water: for, if a given quantity of water, suppose  $A$ , will absorb a given quantity of any salt, suppose  $a$ , I can see no possible reason why  $m A$  should not absorb  $m a$ : for imagining  $m A$  to be divided into portions respectively equal to  $A$ , and equal quantities of salt to be dissolved in each of them; then, from the supposition, each of them will absorb  $a$ ; and when they are all mixed together, as no precipitation will ensue, the sum, or  $m A$ , must have absorbed  $m a$ . But I have no  
 inclina-

- inclination to animadvert upon what seems to be a small mistake of an author, whose various writings do much honour to philosophy in general, nor to involve myself in a dispute with any one. The following experiment may perhaps be thought conclusive against the doctrine of salts being absorbed into the pores of water: I took a large glass receiver, containing near six gallons; into its neck, by means of a hole bored through a cork, I cemented a small glass tube; and having filled the whole up to the middle of the tube with water, I dropped in a piece of sea salt, weighing less than one forty thousandth part the weight of the water: the water instantly rose in the tube, continued sinking during the solution, but at last remained as much elevated as it would

would have been had there been no more water than what would have been sufficient to dissolve it. In making this experiment, the receiver should not be touched by the hand, for its parts suddenly expanding themselves occasion an instantaneous sinking of the water in the tube, as I have frequently experienced, and might thus induce a suspicion of the water's not being elevated by the addition of salt. I would not be understood from these experiments to deny the porosity of water, since philosophers have thought that the passage of light through it, and other phænomena indicate the existence of vacuities in it; but I cannot believe, however solution be carried on, that the smallest quantity of salt can be dissolved in the largest quantity of water, without increasing its magni-



tude. The cause of the water's sinking during solution doth not appear to be so certain; the escape of air, to which all the appearances induced me to refer it, and to which it may perhaps still be owing, seems to be liable to some objections, not only from the experiments I have before mentioned, but from the following.

#### EXPERIMENT XII.

I took two matraffes of equal dimensions, one filled with common water, the other with boiled water. I poured into them equal quantities of oil of vitriol; in the first there seemed to be an universal precipitation of air, as it were, from every particle of the fluid, which, by little and little, formed itself into larger bubbles, and, ascending through the neck, escaped; in the other, hardly  
any

any air could be observed, the water sunk during the solution of the acid very apparently, yet  $\frac{1}{1000}$ th part of the water's weight of acid caused a sensible elevation: so that, whatever may be thought of the cause of the water's sinking during the solution of a salt, the principle of its being to a certain degree imbibed into the pores of water seems in no case to be true, whether the salt be in a concrete or fluid form. This subject may receive some illustration from what is observed in the freezing of water; ice from common water is always specifically lighter than water, from its retaining in its concrete form several air-bubbles, which enlarge its bulk without adding to its weight; this ice, when put into a matrafs, after the manner in which all the preceding experiments

periments with salts were made, would elevate the water most upon the first immersion: the water would sink as the ice melted; equal portions of ice would produce equal elevations both before and after solution; the air would be separated in a form more or less visible, according to the circumstances in which the experiment should be tried; and not the smallest portion of ice could be dissolved without increasing the bulk of the whole. Salts do not seem to differ much from ice in the manner of their formation, and as similar phenomena attend their solution in water, why may we not explain them from the same cause? But if any one should think differently, notwithstanding the experiments which have been produced, I profess myself

self

self extremely ready to listen to any reasoning founded upon experiment which may tend to prove my opinion to be erroneous; having no partiality for any thing but truth, nor being ashamed of ignorance or mistake in any matter, respecting the comprehension or explication of even the minutest operation of nature: *ego quidem hoc sum contentus, quod licet quo quidque fiat ignorem, quid fiat intelligo.*

[This Essay has had a flattering attention paid it by foreigners; I know it has been translated into the French, and I believe it has been translated into the German language.]

self extremely ready to listen to any  
 reasoning founded upon experiments  
 which may tend to prove my opi-  
 nion to be erroneous, leaving no  
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 not being ashamed of ignorance or  
 mistake in any matter, respecting the  
 comprehension or explanation of even  
 the minutest operation of nature;  
 the greatest for the most common, and  
 the most sublime for the most trivial;  
 the most difficult for the most easy.

I have been a student  
 of the French, and I believe  
 it has been translated into the  
 English language.



THE following Essay was written near twenty years ago; a few copies of it were printed, but not published, in 1771: it was animadverted on by the late Doctor Hawkesworth in the Gentleman's Magazine, by the authors of the Journal Encyclopedique, and in some other periodical publications about that time. There is a speculation advanced in it relative to the perceptivity of vegetables, which I would not be thought to maintain

with any pertinacity, yet I am pleased to see that so able a writer as Dr. *Percival* has supported the same side of the question.\* Whether vegetables have or have not the faculty of perception, is one of the many questions which it is pleasant to discuss, but difficult to decide; the arguments in favour of the affirmative side are such as rather invite assent than extort conviction.

The opinion which I have endeavoured to illustrate, has not, I find, that novelty to recommend or to disgrace it, which, when I wrote the Essay, I thought belonged to it; it has been incidentally adopted by ancient and modern authorities of great weight: I will quote the words of four distinguished authors to this purpose.

\* Manchester Mem. Vol. II. page 114.

*Stobæus* acquaints us, that *Plato* thought plants were living bodies, endued with sensation. His words are

—Πλατων και τα φυτα εμψυχα ζωα. Φανερον και απο τς σαλευεσθαι, και εντεταμενους εχειν τς κλαδους, και ταις επαγωγαις εικειν, και παλιν σφοδρως αναχαλασθαι και αισθητικα, ενια δε και λογικα.\* —*Cardanus* expresses

himself in the following terms: *Nobiliores metallicis plantæ sunt, atque in his quædam sensus imago relucet. Etenim et odisse et amare plantas, et membra habere functionibus opportuna, satis clarum esse puto. †—Rursus quaeritur, quare in mari quædam plantæ sentiant, in terra non? At hoc inferius exponetur. Igitur forsan in crasso aëre aliquam plantam, quæ sensum habeat, et similem carni imperfectæ,*

\* *Stob. Ecl. Phys. L. i. p. 87.*

† *Cardan. de Subtil. L. iii. de Plantis.*

*qualis est cochlearum et piscium, non erit impossibile.\**

The words of Ray are very remarkable—*Facultas sentiendi animalibus tam propria censeri solet, ut eorundem differentia essentialis a philosophis constituatur. Verum plantæ nonnullæ Æschynomænæ veteribus dictæ, recentioribus vivæ, et sensitivæ, et minosæ, haud obscura sensus indicia produnt.* He then mentions the most remarkable motions observable in sensitive plants, and asks, *Quomodo hæc fiant, si sensum omnem et motum spontaneum iis denegemus mechanica aliqua ratione explicare perdifficile est? †*

Lastly, the animal nature of vegetables is acknowledged as probable by Spallanzani, who is justly esteemed the greatest naturalist of

\* Id. de Rer. vari. L. vi. c. 22.

† Ray. Hist. Plan. Tom. I. l. 18.

the present age. Having remarked that *Haller* was the first who shewed that in birds the foetus exists before foecundation, and that he himself extended the discovery to different species of amphibious animals, and to some sorts of plants, he adds, "Hence we have a new and striking point of analogy between plants and animals to be added to the many others long known; and hence the suspicion that these two tribes of organized bodies compose, perhaps, but one immense family, receives strong confirmation." \*

It would be disingenuous to conceal the sentiments of those who think that perception does not in

\* Dissert. on the Nat. Hist. of Anim. and Veget. by Abbè Spallanzani. Engl. Transf. Vol. II. p. 315.



any degree belong to plants; I will lay before the reader some authorities on this side of the question, that the weight of the argument, *ad verecundiam*, may be equal on both sides.

*Sir John Hill*, in his *Vegetable System*, places the difference between vegetables and animals in a system of nerves which belongs to animals, but not to vegetables: “Vegetables,” says he, “are placed by nature in a middle state, between the mineral and the animal classes: superior to the mineral in having organized bodies, inferior to the animal kinds in wanting a nervous system. They are capable of growth, but below sensation.\*

*M. Gleditsch* says—*Les plantes appartiennent à la classe des corps vivans*

\* *Hill's Veg. Sys. B. II. p. 1.*

*dans la nature. Elles ont leur structure exactement régulière, tout comme les animaux; avec lesquels elles ont beaucoup de ressemblance par rapport à leur génération. Une des principales propriétés, celle que nous nommons l'irritabilité, leur est pareillement commune; mais pour l'autre, savoir la sensibilité, elle demeurera toujours propre aux animaux.\**

The opinion of *Haller* is thus expressed—By irritability, *M. de Haller* means, that property which certain parts of living bodies possess, of contracting when wounded, or even when touched, independent of the will of the animal that is subject to the experiment, and without its feeling any pain. A property which plants seem also to partake, and

\* L'Acad. des Scien, Berlin, 1765. p. 52.

which being distinct from sensibility, does not depend on the same organs. He endeavours to prove, that irritability resides exclusively in the muscular fibres, and sensibility in the nerves. \*

\* Memoirs of Haller, by Tho. Henry, p. 72.

## E S S A Y III.

*On the Subjects of Chemistry, and their  
general Divifion.*

ALL terrestrial existencies may, in one view or other, be considered as the subjects of Chemistry: they are ufually divided into three diftinct claffes, called the three kingdoms of nature; the first includes Minerals, the second Vegetables, the third Animals. Natural history, in an extended fenfe, comprehends the knowledge of whatever relates to terrestrial existencies, exclusive of the moral actions of man, which conftitute the basis of civil history; and of the phyfical actions of bodies one upon

upon another, which are the foundation of natural philosophy.

Mineralogy is that part of natural history which treats of whatever is found upon the surface, or dug out of the bowels of the earth, except animal and vegetable substances: some have excepted water also, and denominated that branch of science which explains the properties of water, Hydrology. And indeed, many chemists have thought proper to consider water, as not appertaining to any of the three kingdoms of nature; but it hath no better right to be distinguished from a solid, elastic, diaphanous mineral, than a melted metal hath to be distinguished from the same metal when concreted into a solid form: in their different states of fluidity and solidity they will have different properties;



ties; but should not, from such accidental changes as are effected by minute variations of heat, be referred to different classes: had water been called melted ice, no one would have scrupled to consider it as belonging to the mineral kingdom.

The reducing quicksilver into a solid, malleable metal, by a due degree of cold, was an important discovery in physics: we learn from thence to consider all fluid bodies, such as water, oils, spirits, æthers, and probably the air itself, as convertible into solids without the introduction of any frigorific particles, but simply by a diminution of heat; and all solid bodies, as convertible into fluids, without suffering any other change in their constitution, except what arises from the volatilization of such of their prin-

ciples, as cannot sustain the degree of heat requisite to render the rest fluid.

Mineralogy is principally employed in arranging similar bodies under the same, and dissimilar bodies under different denominations. It judges of similarity two ways; either from the similarity of the external appearance, or from the similarity of the internal constitution. The knowledge of the similarity of the internal constitution of bodies is acquired, chiefly by regarding the changes produced in them by the action of fire, or the action of menstruums; that of the external appearance by regarding the colour, configuration of the superficial parts, consistency, and weight. From the knowledge of the constituent parts of bodies is derived their œconomical

mical application, their use in medicine, agriculture, metallurgy, and other arts: from the similarity of the external appearance, is derived a suspicion concerning the identity of the internal constitution; a suspicion, serviceable in suggesting conjectures to philosophic minds, relative to the generation, transmutation, and destruction of natural bodies.

Most mineralists have contented themselves with classing the various species of fossils according to their most obvious qualities, and have thereby referred things very heterogeneous to the same genus. In the animal and vegetable kingdoms, the external appearance is of essential use in helping us to reduce them into genera and species: indeed, when from a resemblance in one or

two particular parts of a plant or an animal; as from the figure of the leaves, or the number of stamina; from the shape of the hoof, or the number of teeth, we venture to arrange them under the same general denomination, great confusion will arise, if we suppose that general denomination to infer a resemblance more extensive than the idea from whence it was derived; nature often admitting a similarity in some particulars, coexistent with the greatest dissimilarity in others: it is not probable however, that *Linnaeus* in classing the productions of nature ever entertained such a supposition, and he seems therefore to have been uncandidly censured. But when the whole external appearance of a plant, or an animal, is taken into consideration, it is far easier to re-  
fer

fer it to, a particular class, than from a chemical inquiry into its internal constitution. In fact, the internal constitution depends, in a great measure, upon the same principle from which the external figure is formed. From the configuration of the vascular system, through which nutrition is conveyed to every part of a plant or an animal, is derived the external figure; and from the same configuration the internal properties seem to arise: for plants become acescent or alcalescent, sweet or bitter, poisonous or salubrious, according to their different natures, though they be planted in the same soil, and fed with the same food, that being changed and elaborated, by processes which we can neither understand nor imitate, into different fluids by the different organizations, and, I



had almost said, digestive powers of different plants. The case is quite otherwise with respect to minerals, the external appearances conveying to us little real knowledge; they may be the same in different bodies, or different in the same body.

*Sir Isaac Newton* has proved, that the colours of natural bodies depend upon the thickness and density of the component parts, and consequently that minute changes in either of these qualities will make very considerable changes in the colour: this philosophy is confirmed by, and serves at the same time to explain, many appearances in chemistry. Crystals of quicksilver in *aqua fortis*, are white, yellow, or red, according to the degree of heat to which they have been exposed; whilst on the other hand, the same

quicksilver corroded into a saline mass by oil of vitriol, remains perfectly white in all degrees of heat, but by the affusion of water is changed at once into a vivid yellow, which is of different shades according as the water is hot or cold, or as the mass hath been more or less freed from its adhering acid by calcination. Iron and lead, and most other metals, undergo similar changes of colour from calcination and precipitation, so that nothing seems more uncertain than the classing of bodies from a respect to their colour. This uncertainty of colour, according as the heat is various, is much felt and complained of by enamellers, and the makers of artificial gems.

The configuration also of the superficial parts is a very uncertain

characteristic of the specific nature of a mineral : metallurgists are sensible of this ; they are obliged in many cases to have recourse to fire, before they can pronounce concerning the metal contained in an ore, whether it be lead or silver, iron or antimony. We have a notable instance of this uncertainty in what is called the stellated regulus of antimony ; the crystallization on the surface resembling the radiations of a star, the scales of a fish, branches of trees, fibrillæ of feathers and other matters, according to certain diversities of circumstances attending the process. I do not deny but that a definite degree of liquidity in the *regulus* and *scoria*, a definite quantity and quality of the *scoria*, and a proper precision in some other matters, would ever produce a definite arrangement of the superficial parts ;

parts; but it is certain that a small variation in any of these will make a great change in the outward and inward appearance of the regulus, without affecting in any sensible manner its internal composition. Another instance will shew the imperfection of this external method of classification still more obviously: in several portions of water let there be dissolved nitre, sea salt, alum, borax, sugar, saccharum saturni, corrosive sublimate, &c. or any combinations of these salts, the several solutions will still be equally colourless and transparent, and by a sufficient degree of cold suddenly applied would be concreted into solid bodies, not to be distinguished from one another by their colours, figures, consistencies, nor (so the experiment might be managed) specific gravities.

By

By these instances from chemistry, we can apprehend how there may be a perfect similarity in the external appearances of bodies, when their internal constitutions are wholly different, and a dissimilarity, when they are wholly the same. The minerals produced by nature are analogous to these of art, and hence we may infer the great confusion and obscurity which must necessarily attend a natural History of Minerals, when it is founded only on the external appearance.

Sensible at last of this imperfection, the composers of systems of mineralogy have availed themselves of the assistance of chemistry, and have endeavoured to class minerals according to their internal properties. This method is perfect in its kind ; and in particular instances  
deserves



deserves greater or less attention, according as the analysis of minerals is more or less complete: in many cases however it is too general and abstracted for common use. For instance, all earths or stones which by a certain assignable degree of heat, and with a certain quantity of saline additions, are convertible into glass, may be called vitrifiable earths; all earths or stones which in the same degree of heat, and with the same quantity of saline additions, or without them, are not convertible into glass, but into quicklime, may be called calcareous earths; and all earths or stones which under similar circumstances remain unaltered in their properties, may, with respect to the other two kinds, be called refractory earths. This is all we can learn from chemistry

mistry relative to the comparative natures of earths, when exposed to a given degree of heat; and hence fish-shells, chalk, limestones, and marbles would be included in the same class: but to answer the purposes of common life, it will be necessary to make a more particular division of them, which can only be done after the generic idea hath been established, by contemplating the external appearances; in which view the colour or figure, or both together, would be principally respected; as in fact we see they are in the distinction of the Italian *Antico's* as *Marmore Nero, Giallo, Rosso di san guisto; di Fiorenza; Pæfino; Alberino di Monte Gallicano, &c.* all of which are convertible into quick-lime, but from their different colours, superficial contextures, and capabilities

lities of receiving different polishes, they have become of different values in a commercial light, and therefore are not improperly distinguished in a system of mineralogy. In like manner, though a chemical examination by fire would probably refer diamonds, emeralds, rubies, topazes, and other stones generally denominated precious, to the class of flints; yet since men have annexed a fanciful value to these pebbles from their pellucidity, colour, hardness, and other external attributes, it would be a great defect in a mineral system not to have them particularly specified and described.

But to discriminate common limestones, or common flints into different species, from a minute variation of the figure or the colour; to class pyrites, or combinations of sulphur  
and

and iron, under the specific denominations of spherical, hemispherical, pyramidal, cubical, &c.; to divide, as is usually done, the ores of the same metallic substance into a great variety of kinds, when an assay will give no difference either in the quantity or quality of the metal contained in them, or of the matter by which they are mineralised, seems to be a *multiplicatio entium præter necessitatem*, and tends rather to obscure and circumscribe, than to elucidate and extend our knowledge of nature.

Upon the whole, the great outlines and general divisions of mineral productions may most usefully be made from a chemical investigation of their constituent parts, and where it is expedient for commercial purposes to be more particular,

an

an attention to the external appearance will be proper for that end. A mineralist who considers gypseous alabasters, plaster stone, lamellated gypsums, rhomboidal felinites, *spatum Bononiense*, and a great many other bodies as proper to be distinguished from one another, and who is able to ascribe any particular body to its proper species from considering its external appearance, is possessed of a particular kind and degree of knowledge: He who besides being acquainted with the external appearances, is able to prove that all these different bodies are composed of a calcareous earth, united to the vitriolic acid; and thus make several species of things coalesce together, and unite, as it were, under one general conception, hath a knowledge of these bodies

different



different in kind, and superior in degree. By this sort of knowledge the memory is much relieved, and the mind, ever grasping after universal truths, is gratified with the acquisition of general ideas. These two very different kinds of knowledge belong to every part of mineralogy, in different views each of them is of indispensable use, and a perfect system of mineralogy should include them both.

If it be asked what are the discriminative characteristics of minerals, vegetables, and animals, as opposed to one another, I plainly answer that I do not know any, either from natural history or chemistry, which can wholly be relied on.

Systematic distinctions, and specific divisions of things, are useful in enlarging the comprehension of the mind ;

mind; by methodizing the objects they seem to extend the boundaries of knowledge: but having no real foundation in nature, they should not be depended on too far; they often perplex or impede the progress of a curious inquirer. This prepossession in favour of systematic arrangements, operates more forcibly upon us as the ideas to which it is usually annexed become the more abstracted. The strongest analogies are overlooked, the plainest reasonings thought fallacious, and decisive experiments inconclusive, when their tendency is to subvert a distinction, of which we had wrongly supposed Nature herself the author. Every one thinks that he knows what an animal is, and how it is contradistinguished from a vegetable, and would be offended at having his knowledge que-

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stioned thereupon. A dog or a horse, he is truly persuaded, are beings as clearly distinguished from an herb or a tree, as light is from darkness; yet as in these, so in the productions of nature, the transition from one to the other is effected by imperceptible gradations.

The loco-motive powers which appertain to most animals, whether they proceed from the *Cartesian* mechanism, or from sensation, are so manifest in quadrupeds, birds, fishes, and insects, that in our first and superficial inquiries into nature, we are apt to consider the possession or want of these powers, as making a decisive and essential difference between animal and vegetable bodies; and it is not without a certain degree of regret, as it were, that we find ourselves obliged to predicate

animality concerning a great variety of beings, which are destitute of every power of progressive motion. If at the same time we happen to have entertained some preconceived opinions, no matter whence they have been derived, concerning the usual shapes of animals, (tho' they are far more different from one another than some of them are from vegetables) our repugnancy to the admitting a being of the outward form of a shrub, into the class of animals, is much increased. Hence have proceeded most of the objections which have been made to the fine discoveries of *Peyssonel*, *Jussieu*, *Ellis*, and others, relative to the animal nature of corals, madrepores, millepores, corallines, sponges, and a numerous tribe of bodies which

the very ingenious labours of *Marsigli* had formerly removed from the mineral kingdom, where they had been placed by *Woodward* and other Mineralists, and allotted to that of vegetables.

If rejecting spontaneous motion and figure as very inadequate tests of animality, we adopt perception in their stead; no doubt, he would be esteemed a visionary in Philosophy who should extend that faculty to vegetables; and yet there are several chemical, physical, and metaphysical reasons which seem to render the supposition not altogether indefensible.

The greater the quantity of perception existing in the universal system of creation, the greater is the quantity of happiness produced; and the greater the quantity of happiness  
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produced, the greater is the goodness of the Deity in the estimation of beings with our capacities. The latter part of this proposition needs no proof; and the former is liable but to one objection, and that grounded upon a false supposition. If, it may be urged, all the species of percipient beings be not accommodated with objects congruous to their faculties of perception, and productive of more pleasure than pain to the whole species taken collectively, then the animation of that matter of which they consist is an introduction of evil, and no test of benevolence. This may be granted; but in all the species of beings which come within the observation of our senses, the supposition of their not being furnished with objects suited to their wellbeing is evidently not

true, and therefore ought, from analogy, to be rejected with reference to such as by their magnitude, their minuteness, or their dulness of perception escape our examination.

That animals should feed one upon another, is a law of nature full of wisdom and goodness, life and happiness being indefinitely multiplied thereby. For a given quantity of what are called vegetables, annually produced upon a globe of a given diameter, being sufficient but for the support of a given number of herbaceous animals, whose place in the universe not admitting their immortality, it hath been wisely contrived that their bodies, which from their structure must perish, should in ceasing to live, become the instruments of supporting life in beings, which could not by any other

other means have had an existence, at least upon this globe; and of the other parts of the universe we know nothing except from analogy, and from that we must conclude that the τὸ πᾶν, be it finite or infinite, is as full of life as this particular part with which we are connected. Nay, animated matter, containing as it were the concentrated virtue of many vegetables, serves for the support of life, and the consequent communication of happiness in a far more ample manner than vegetables themselves; animal substances in equal weights furnishing more nutriment than vegetable. It is by Death, a seeming imperfection in his workmanship, that the Deity preserves vegetable life, supports the animal kingdom, daily regulates and renews the œconomy of nature,

and continues this wonderful system of things in full youth and vigour, not interrupted by disease, nor enfeebled by old age.

No objection therefore to the animality of vegetables can be brought from any considerations respecting their daily destruction ; for the destruction of animals by other animals, the *bellum omnium in omnia*, is an universal law of nature, derived from the same benevolence to which we attribute creation itself. If then every part of the vegetable kingdom hath a degree of perceptivity, however small, there will be a gain of happiness to the whole system ; the aggregate may be of a value not to be overlooked by him, to whom the existence of all things is equally possible, and from whom all created

existences are equally distant in perfection.

Wherever there is a vascular system, containing a moving nutritive *succus*, there is life ; and wherever there is life there may be, for ought we can prove to the contrary, a more or less acute perception, a greater or less capacity for the reception of happiness : the quantity, indeed, of which after we have descended below a certain degree of sensibility, will (according to our method of estimating things, which is ever partial and relative to ourselves) be small in each individual ; yet is the existence of it in the nature of things possible, from the analogy of nature probable : and who can tell whether in a system of nature, confessedly contrived for the production of the greatest possible



sible good, it may not also be necessary?

It should be well weighed by the metaphysicians, whether they can exclude vegetables from the possession of the faculty of perception, by any other than comparative arguments; and whether the same kind of comparative reasoning will not equally exclude from animality those animals which are provided with the fewest and the obtusest senses, when compared with such as are furnished with the most and the acuteest. The perception of a man (though it may be doubted whether there are not several animals which have all the senses more acute) seems to be indefinitely greater when compared with that of corallines, sea-pens, and oysters, than the perception of these, which are allowed to be animals, doth when  
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compared with the signs of perception manifested by a variety of what are called vegetables. Sponges open and shut their *mamillæ*, corals and sea-pens protrude or draw back their suckers, shell-fish open or keep close their shells in search of food or avoidance of injury ; it is from these and similar muscular motions that we judge the beings to which they belong to have perception, that is, to be animals. Now in the vegetable kingdom, we may observe the muscular motions of many plants to be, to the full, as definite and distinguishable as those of the class of animals just mentioned. The plants called *Heliotropæ* turn daily round with the sun ; by constantly presenting their surfaces to that luminary, they seem as desirous of absorbing a nutriment from its rays, as a bed  
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of muscles doth from the water, by opening their shells upon the afflux of the tide. The *Flores Solares* are as uniform in their opening and shutting as animals are in their times of feeding and digesting; some in these motions do not observe the seasons of the year, but expand and shut up their flowers at the same hour in all seasons; others, like a variety of insects which appear, or not, according to the heat of the weather or climate, open later in the day, or do not open at all, when they are removed from a southern to a more northern latitude. Trefoil, woodsorrel, mountain ebony, wild fenna, the African marigold, &c. are so regular in folding up their leaves before rainy weather, that they seem to have a kind of instinct or foresight similar to that  
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of ants ; which however deserts many of them as soon as they have propagated their kind, by shedding their pollen. Young trees, in a thick forest, are found to incline themselves towards that part through which the light penetrates, as plants are observed to do in a darkened chamber towards a stream of light let in through an orifice, and as the ears of corn do towards the south. The roots of plants are known to turn away with a kind of abhorrence from whatever they meet with which is hurtful to them, and to desert their ordinary direction, and to tend with a kind of natural and irresistible impulse toward collections of water placed within their reach : many plants experience convulsions of their *stamina* upon being slightly touched. Whatever can produce  
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any effect upon an animal organ, as the impact of external bodies, heat and cold, the vapour of burning sulphur, of volatile alcali, want of air, &c. are found to act also upon the plants called sensitive. But not to insist upon any more instances, the muscular motions of the *Dionæa Muscipula*, lately brought into Europe from America, seem far superior in quickness to those of a variety of animals. Now to refer the muscular motions of shell fish, and zoophytes, to an internal principle of volition, to make them indicative of the perceptivity of the being; and to attribute the more notable ones of vegetables, to certain mechanical dilatations, and contractions of parts occasioned by external impulse, is to err against that rule of philosophizing which assigns the same causes



causes for effects of the same kind. The motions in both cases are equally accommodated to the preservation of the being to which they belong, are equally distinct and uniform, and should be equally derived from mechanism, or equally admitted as criterions of perception.

I am sensible that these and other similar motions of vegetables may by some be considered as analogous to the automatic or involuntary motions of animals; but as it is not yet determined amongst the Physiologists, whether the motion of the heart, the peristaltic motion of the bowels, the contractions observable upon external impulse in the muscles of animals deprived of their heads and hearts, be attributable to an irritability unaccompanied with perceptivity, or to an uneasy sensation, there

there seems to be no reason for entering into so obscure a disquisition; especially since irritability, if admitted as the cause of the motions of vegetables, must, *a fortiori*, be admitted as the cause of the less exquisite and discernible motions of beings universally referred to the animal kingdom.

Physical observations concerning the generation, nutrition, organization, life, health, sickness, and death of plants, help us as little towards the establishing a discriminative characteristic between them and animals, as metaphysical speculations relative to the quantity of happiness, or degrees of perceptivity.

The eastern practice of fecundating the female palm tree by shaking over it the dust of the male, which *Herodotus* mentions in his account of  
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the country about *Babylon*, and of which Dr. *Hasselquist* in the year 1750 was an eye witness, was not unknown to *Aristotle* and *Pliny*: but the ancients seem not to have carried the sexual system beyond that single instance, which was of so remarkable a kind, that it was hardly possible for them to overlook it; at present there are few botanists in Europe who do not admit its universality. It seems generally agreed, that a communication of sexes, in order to produce their like, belongs to vegetables as well as to animals. The disputes subsisting among the anatomists, concerning the manner in which conception is accomplished, whether every animal be produced *ab ovo femellæ*, or *a vermiculo in semine maris*, are exactly similar to those amongst botanists concerning

the manner in which the *farina fœcundans* contributes to the rendering the seed prolific : but however these doubts may be determined, they affect not the present inquiry, since it is allowed on all hands, that as the eggs of oviparous animals, though they arrive at their full magnitude, are incapable of being vivified by incubation, unless the female hath had commerce with the male : so the dates of female palm trees, and the fruits of other plants, though they ripen, and arrive at maturity, will not grow unless they have been fœcundated by the *pollen* of the male.

In like manner, notwithstanding the diversity of opinion which hath long subsisted, and in a matter so little capable of being enlightened by experiment, probably ever will  
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subsist, concerning the *modus agendi* by which nature elaborates the nutritive fluid, administers it to the foetus in the womb, and produces an extension of parts; yet since a *placenta* and an umbilical chord are by all thought essential to the effecting these ends; and since the cotyledons of plants, which include the *corculum* or first principle of the future plant, with which they communicate by means of tubes branched out into infinite ramifications, are wholly analogous to the placenta and umbilical chord of animals, we have great reason to suppose that the embryo plant and the embryo animal are nourished and dilated in their dimensions after the same way. This analogy might be extended and confirmed by observing that the lobes, within which the foecundated germ



is placed, are by putrefaction converted into a milky fluid, well adapted as an aliment to the tender state of the plant.

Expiration and inspiration, a kind of larynx and lungs, perspiration, imbibition, arteries, veins, lacteals, an organized body, and probably a circulating fluid appertain to vegetables as well as to animals. Life belongs alike to both kingdoms, and seems to depend upon the same principle in both: stop the motion of the fluids in an animal limb by a strong ligature, the limb mortifies beyond the ligature, and drops off; a branch of a tree under like circumstances, grows dry, and rots away. Health and sickness are only other terms for tendencies to prolong or to abridge the period of life, and therefore must belong to both

both vegetables and animals, as being both possessed of life. An east wind, in our climate, by its lack of moisture, is prejudicial to both; both are subject to be frost-bitten, and to consequent mortifications; both languish in excessive heats; both experience extravasations of juices from repletion, and pinings from inanition; but can suffer amputation of limbs without being deprived of life, and in a similar manner both form a *callus*; both are liable to contracting diseases by infection; both are strengthened by air and motion: *Alpine* plants, and such as are exposed to frequent agitation from winds, being far firmer and longer lived than those which grow in shady groves, or hot houses; both are incapable of assimilating to their proper substance all kinds of food;

for fruits are found to taste of the soil, just as the urine, and milk, and flesh, and bones of animals, often give indications of the particular *pabulum* with which they have been fed: both die of old age, from excess of hunger or thirst, from external injuries, from intemperature of weather, or poisoned food.

Seeds of various kinds retain their vegetative powers for many years; the vivification of the *ova*, from which the insects occasioning the smut in corn, and the *infusoria animalcula* observable in water after the maceration of plants, probably proceed, may be esteemed a similar phænomenon. It is not yet clearly decided amongst naturalists, whether the seeds of mushrooms, of mushrooms, and of the whole class of *Fungi*, be not in a tepid, humid *matrix*,  
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changed into vermicular animals; which lose in a little time their power of spontaneous motion, coalesce together, and grow up into these very singular plants: the quickness of their increase, and the irresistible force with which the least mouldiness propagates itself, and destroys the texture of the bodies upon which it fixes, seem to point towards an animal nature.

Different vegetables require different soils, as different animals do different food for their support and well being: aquatics pine away in dry sandy grounds, and plants which love rocks and barren situations, where they imbibe their chief nutriment from the air, become diseased and putrid in rich bogs and swamps.

There are aquatic animals which become immovable and lifeless

when the rivulets in which they subsisted happen to be dried up, but which recover their life and locomotive powers upon the descent of rain: in this circumstance they are analogous to the class of mosses among vegetables, which, though they appear to be dried up, and ready to crumble into dust during the heats of summer, yet recover their verdure and vegetable life in winter, or upon being put into a humid soil.

*Trembley, Bonnet, and Spallanzani* have vastly amplified our views of nature; they have discovered to us divers species of animals, which may be cut into a variety of pieces without losing their animal life, each piece growing up into a perfect animal of the same kind: the multiplication of vegetables by the planting  
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of branches, suckers, or joints of roots is a similar effect. The reproduction of the legs of craw-fish, lobsters, crabs, of the horns and heads of snails, legs of lizards, of the bony legs and tails of salamanders, when by accident or design they have been deprived of them; and the great difference in the time of the reproduction, according to the season of the year in which the limb is lost, are wonders in the animal kingdom, but wholly analogous to the repullulation of trees after lopping.

All plants, except those of the classes *Monœcia* and *Diœcia*, are hermaphrodites; that is, they have the male and female organs of generation within the same empalement. Shell-fish, and such other animals as resemble vegetables in not being  
able

able to move far in search of mates, with which they might propagate their kind, are hermaphrodites also: *Reaumur* hath proved that vine fretters do not want an union of sexes for the multiplication of their kind.

From the conjunction of animals of different species are produced *hybrides*, which in many cases cannot propagate: botanists have tried the experiment, and by fœcundating female flowers with the male dust of another species, have produced hybridous plants, of an intermediate shape, the seeds of which are barren and effete.

Trees shed their leaves as birds do their feathers, and hirsute animals their hair. At particular seasons the juices of vegetables move with fulness and vigour; at others they are less plentiful, and seem to stagnate;

stagnate; and in this they resemble dormice, bats, frogs, and numberless other animals of cold blood, which lie torpid and destitute of every sign of life during the winter time; the action of the lungs and of the heart being, if any, imperceptibly weak and languid.

Few, if any animals can exist without a reciprocal succession of sleep and vigilance, and the younger the animal, the greater is its propensity to sleep: the same alternatives seem necessary for the health of several vegetables; a great variety of plants fold up their leaves, and seemingly compose themselves to rest, in the night time, and this disposition for sleep is more remarkable in young plants than in old ones; nor does it, as might be suspected, depend upon the influence of light  
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or heat, since plants in hot houses, where the heat is kept at the same degree, fold up their leaves at a stated time in the evening, and expand them in the morning, whether the light be let in upon them or not. It may deserve to be inquired, whether by a relaxation of fibres these plants become subject to a more copious perspiration during sleep than in their state of vigilance, as *Sanctorius* hath proved to be the case in animals.

There is a great diversity, but a regular succession in the times, in which animals of different species feel the *æstrum*, by which they are stimulated to the propagation of their respective kinds; an order equally determined, is observable in the times of accomplishing the *sponsalia* of plants. The periods of incubation

cubation in oviparous, and of gestation in viviparous animals are not more various in different species, nor probably more definite in the same, than the periods requisite for the germination and maturation of different seeds. By the influence of heat and cold, abundance and scarcity of nourishment, the seasons of propagating may be somewhat accelerated or retarded in animals as well as in vegetables: the effects of a cold ungenial spring are as remarkable in the retardation of the procreative intercourses of birds and beasts, as in the stoppage of the leafing of trees, or the flowering of shrubs. In a word, there are so many circumstances in which the anatomy and physiology of some plants agree with those of some animals, that few, I believe, can  
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be mentioned in which they disagree.

When it is considered that animals are either mediately or immediately wholly nourished from vegetables, it might be expected, *a priori*, that the products obtainable by a chemical analysis from the two kingdoms should be different rather in quantity than quality, and that we could not from thence discover any criteria by which they might be distinguished from one another: this observation is confirmed by experiment. Animals, it is true, in general yield a greater proportion of a volatile alkaline, than of an acid salt by distillation; vegetables on the contrary abound in acid, and yield not any volatile alkali, unless with the last degree of heat, or when they have undergone putrefaction:

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in saying this, I am aware that I differ from the opinion commonly received. Mustard seed, water cresses, horse radish, and other plants of the *tetradynamia* class are generally said to contain a volatile alkali already formed, and to yield it with the heat of boiling water; from none of these however could I ever obtain by that heat a phlegm which would give a precipitation with corrosive sublimate, the most indubitable test of a fluid's containing even the minutest portion of volatile alkali; the pungent smell seems to have been mistaken here, as *Sir John Pringle* hath well observed the *fætor* to have been in the putrefaction of many animal substances, as proceeding from a volatile alkali; and which may, perhaps, be with greater truth attri-

buted to a volatile oil, a small portion of which is sometimes procurable from pepperwort, by the heat of boiling water impregnated with sea salt. However, as some animals, and some parts of most animals yield a portion of acid, and as most vegetables, by a strong fire in close vessels, or when converted into soot, afford a volatile alkali, altogether similar to that obtained from animal substances, we cannot from these circumstances establish any distinctive mark between the two kingdoms.

With respect to Minerals indeed, chemists think that they have found out an infallible and universal criterion, by which they may be distinguished from every animal or vegetable substance. All bodies from which we can obtain an oil by distillation,

tillation, or otherwise, are supposed to belong to such substances as have enjoyed an organic life; no mineral, it is said, containing any: this is a sensible distinction, and yet it is not perhaps in extreme cases wholly to be relied upon. When a vegetable or animal is distilled in close vessels, the stronger the fire is, the more oil is obtained; what first passes into the recipient is more clear and limpid than what comes over towards the end of the operation: it may be presumed, however, that what remains adherent to the coal in the retort, and which no violence of fire can separate, is not essentially different from the last portions which are distilled; yet this, be it fixed oil or phlogiston, is no wise different from what enters into the composition of metallic substances, and of

minerals, perhaps, of all kinds. Zinc burns with a flame resembling that of charcoal; lead and tin burn like rotten wood; iron and other metals may be burnt to ashes in the open air, but like charcoal cannot be decomposed in close vessels; spirits of wine burn like sulphur, charcoal and metallic substances without producing any foot; yet from spirits of wine an oil may be obtained: Why should the phlogiston of metals be thought of a nature wholly different from the oil which so obstinately adheres to charcoal, or from that which seems to enter into the composition of vinous spirits?

Naturalists, as well as chemists, have perhaps too precipitately embraced the opinion, that minerals may be certainly and readily distinguished



guished from the other two kingdoms. A vascular system, a nutritive succus, and a power of producing its like, constitute the abstract idea both of a vegetable and an animal, as contradistinguished from a mineral: this idea is clear and definite in itself; but to determine how far the coexistence of these qualities is in the nature of things necessary, or where any of them ceases to exist, is a question of vast difficulty when applied to particular cases. Stones dug out of quarries, ores out of mines, in general, minerals separated from their *matrices*, are like the dead branches or limbs of vegetables or animals, incapable of receiving increase, except from an external incrustation; but whether the matrices themselves increase, or that being in some cases granted,

whether they receive their augmentation from an external apposition, or an internal assimilation and extension of parts, cannot readily be decided either way. In the *Cretan* labyrinth it hath been observed, that the names of travellers, which have been cut in the rock in former ages, are now in *alto relievo*, and that the older the dates are, the greater is the protuberance, resembling the callus formed by incisions in trees. In the mines of *Chremnitz* in Hungary, which have been wrought for above one thousand years, the ancient roads which had been cut through the rocks are left to grow up; and it is remarked, that they approach one another in a horizontal, and not in a perpendicular direction; the same phænomenon may be observed in the mar-

ble quarries in *Italy*, as is mentioned by *Baglivi* in his Treatise upon the Vegetation of Stones: but whether these, and many similar appearances are to be attributed to the pressure of the superincumbent strata, or to a kind of vegetable growth, is a doubtful point. Rock crystals, amethysts, and various precious stones have been thought by *De Boot* and others to grow like mushrooms; certain it is, that they often contain in them several heterogeneous particles; a circumstance which proves them to have been once in a fluid state, and induces a suspicion that in their formation they may resemble the gums and resins extravasated from various species of vegetables. The vegetation of stones hath been admitted by many, and some have contended that minerals, as well as

animals and vegetables, spring from seed, the greatest rock being nothing but the expansion of the parts of a minute grain of sand.

Salts dissolved in water consist of indefinitely small *molecules*, which, as far as microscopes can inform us, are similar in figure to the large crystals which become visible to the naked eye, and which are formed, as it were, from the expansion of one particle: it will be easily understood, how conformable this mineral crystallization is to the opinion of those, who attribute the growth of animals and vegetables to the *accretion of organic particles* of the same kind. The concentrick crusts of which *stalactites* consist, are not either in their appearance, or their formation, perhaps, unlike the circles annually produced by the stag-

nation of the sap in the bolls and branches of trees. The native gold and silver tufts, which appear to burst through the hardest rocks, and which from their great resemblance to trees, have been called by some arborescent, seem to indicate a kind of vegetation in their formation.

Supposing, however, that we pay no attention to any of these circumstances, yet cannot we form any judgment concerning the internal state of the earth. The greatest depths to which Miners have penetrated even in mountainous countries, which may be considered as excrescencies from the true surface of the earth, or the level of the sea, have scarcely ever equalled one sixteen thousandth part of its diameter; a distance altogether insufficient for the forming any probable conjecture



about the inward constitution of the globe. The *strata* of stones, and veins of minerals, which are met with upon the surface, can give us as little information concerning the internal structure of the earth from which these are probably derived, as the contemplation of the scales of a fish, the feathers of a bird, or the *Epidermis* of a man, would concerning the bones and muscles, the veins and arteries, the circulation of the blood, and the several secretions of an animal body. Many minerals seem in their formation to have been antecedent, others subsequent to the universal deluge ; a great part of the matter constituting the outward shell of the earth, the only part which we can examine, hath been subservient to vegetable or animal life. All the *strata* of limestones, chalks, marbles,

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all gypsums, spars, alabafters, &c. are confessedly of animal origin. The *strata* of pit-coal, and of all bituminous fossils, of some species of flates, whatever may be thought of argillaceous strata in general, the mould every where covering the surface of the earth, and other substances, are supposed, probably enough, to have arisen from the destruction of vegetables; so that I know not whether it would be a very extravagant conjecture which should suppose that all matter is, or hath been organized, enlivened, animated.

Hence may it appear probable, with reverence yet, and conscious ignorance be it spoken, that the *One, Eternal, Incomprehensible God* hath established an uninterrupted concatenation in all his works, which he  
hath

hath submitted to our view. Different individuals hath he mingled together into the same *species*; different species into the same *genus*; different *genera* into the same kingdom; and different kingdoms he hath distinguished, perhaps, but by lines of division too minute for our observation. This strong analogy by which men and minerals, and all intermediate existencies are bound together in a common chain, and thence, it would seem, naturally subjected to a common fate, may appear humiliating to such as have been wont to entertain high notions of the physical dignity of human nature: but it cannot offend nor disquiet those, who feel within themselves faculties essential to the constitution of moral agency, and who from thence become capable at least of retribution,  
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of punishment, or reward in another state.

In the number of our senses, and in the modifications of the intellectual faculties which spring therefrom, we have a great resemblance to many animals which inhabit this planet as well as we. The *genus* to which man belongs includes a great many subordinate *species* ; or, to speak in a manner more conformable to nature, and more consonant to the account we have of its origin, the human species, from the diversities of climate and of food, from changes introduced by disease, and continued, perhaps, by propagation, and from other causes which are unknown to us, hath been branched out into a great many varieties : these, however, are as much distinguished in shape and intellect from  
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one another, as they are from animals which have sprung from a different stock. Anatomists, *whether they consider the brain as an instrumental, or an efficient cause of intelligence*, are agreed in acknowledging a great resemblance between the contents of the human *cranium* and those of quadrupeds; and *Putius* hath proved, contrary to the opinion embraced by *Pliny*, and commonly received, that we have not that medullary substance in a greater proportion than other animals. Nor are we characterized by a circumstance generally esteemed essentially necessary to the support of the human foetus, and exclusively appertaining to our species: nations are mentioned to whom it doth not belong, and whatever degree of credit may be given to that narration, it is



is certain that a great many species of animals have been discovered to which it doth. Notwithstanding this analogy by which we are to be classed with the rest of the animals around us, yet hath it pleased Him who called forth from nothing both us and them, and thankful we ought to be for the preference, to place us at the top of the scale, to make us, as it were, the first term of a series, descending indefinitely by imperceptible gradations, to particularize that class of animals to which we belong, by rendering it capable of forming a moral character. This capability, it is true, is various according to the opportunities of, and capacities for receiving instruction in different species, and in different individuals of the same species: the Orang-outang of the woods of Java,

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the apron-bellied Caffre of the Cape\*, the woolly-headed Negro of Africa, the beardless Savage of America, the dwarfish Inhabitant of the Frigid Zone, the moon-eyed Albino, and the enlightened European, are as different from one another in this circumstance as in outward form: yet wherever it exists even in the smallest degree, there ariseth a proportionable

\* Since the writing of this Essay it has been discovered by Professor *Sparmann*, that the epithet here applied to the Caffres, on the authority of former Voyagers, is not just; and it is now also believed, on good authority, that the Savages of America would resemble Europeans in having beards, if they did not pluck out the hairs by the roots as soon as they begin to appear. If the reader wishes to see an account of the principal varieties of the human race, he may consult *Van Berchem's Tableau*, published in the *Memoires de L'Academie des Sciences*, 1783.

portionable imputability of conduct, a kind of title to the natural or covenanted good, a reasonable subjection to the natural or positive evil, which God hath annexed as sanctions to the laws which he hath thought fit to prescribe for the regulation of the moral conduct of mankind.



## ESSAY IV.

*Some Remarks on the Effects of the  
Cold in February, 1771.*

ON the 12th of February, 1771, about an hour after sun rising, I observed at Cambridge a degree of cold which is very unusual in England, though common enough in more northern climates. *Fahrenheit's* thermometer, made by *Dollond*, as well in the open air, as when covered with snow, stood as low as 6° above 0. The *Cam*, by no means a rapid river, remained unfrozen; at the sides indeed there was a little ice, and some small flakes floating in the

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middle. This is no very uncommon phænomenon. The *Seine* was not frozen at *Paris* in 1709, though the cold continued for two days one degree greater than in the present case. Various reasons have been produced, in order to account for this seeming deviation from the usual course of nature. It hath been generally believed, that the strong current in the *Seine* impeded the congelation: motion will certainly hinder the parts of fluid bodies from acquiring a regular arrangement; but it may be doubted whether it will wholly prevent their coalescence, in any case where the degree of heat is less than what would keep them fluid if they were quiescent. We have frequent instances in chemistry, of saturated solutions of salts remaining perfectly fluid whilst at rest,

and, of. forming thick coagulums upon the least motion. Melted metals, glass, resins, &c. appear to continue fluid for a longer time, after being taken from the fire, by having their parts moved, than if they are left at rest; because the superficies which is exposed to the air is constantly changing, and the whole mass becomes uniformly cold and fixed at once, as soon as it has parted with the heat necessary for its fusion. The most rapid rivers would probably experience a similar change, did the cold in the atmosphere continue long enough to be communicated to the whole body of the water: for upon taking the thermometer out of the snow, which laid upon the bank of the river, and immersing it into the water, it suddenly rose  $26^{\circ}$ , and stood at  $32^{\circ}$ , or higher; so that the

air was very considerably colder than the water: nor is this at all to be wondered at, when we consider that great degrees of cold may be suddenly produced in the atmosphere by causes which do not immediately operate upon other bodies. Thus the influx of colder air from the northern latitudes, or the descent of that which always remains exceedingly cold in the upper parts of the atmosphere in the same latitude, may in a few hours wholly change the air of a particular district: or, if from any peculiar circumstance the air should become unusually dry, and consequently disposed to dissolve much water, a great degree of cold might be almost instantaneously produced; but which could not be communicated to other bodies, in a little time, by so rare a fluid as the air.

During the forementioned degree of cold, a thick vapour was seen rising from the surface, and marking as it were the course of the river. If we attribute the elevation of this vapour to the attraction of the air, rather than to the comparative warmth of the water (for water just beginning to freeze is observed not to lose of its weight by evaporation *in vacuo*), the great cold may be thought perhaps to have proceeded from the solution of water in air which was then carrying on; for the earth was glutted with humidity, and the air was become dry, having been freed from its water by an almost incessant precipitation for three days, under the form of snow or sleet. It is very remarkable, that the extreme cold of January 13, 1709, came on at *Paris*, with a gentle south wind,



and was diminished when the wind changed to the north; this is accounted for by M. de la Hire, from the wind's having passed over the mountains of *Auvergne* to the south of *Paris*, then covered with snow; and by Mr. *Homburg*, from the reflux of that air, which had been flowing for some time from the north. I do not see from what philosophical principle it can be supposed, that the same air in its regress from a southern latitude should be colder than in its progress from a northern; and as to the other opinion, the phænomenon of the cold's increasing upon the wind's changing from north to south, hath been taken notice of in other places, where there was no snow to refer it to. May it not deserve to be considered, whether the sudden solution of large quantities



ities of aqueous vapours, brought from the south into a dry northern air, be not a cause adequate to the effect produced? The solubility of water in air is distinctly mentioned by Dr. *Halley*, in the *Philos. Trans.* N<sup>o</sup> 192; and in the 6th Vol. of the *French* Encyclopedie, published in 1756; and more fully and ingeniously treated of by Dr. *Hamilton* in 1765: the cold attending the solution is a phænomenon similar to that attending many other chemical solutions, and is in a less degree sensibly felt by every one who goes into a room newly washed, or street in the summer-time lately watered. Upon taking the thermometer out of the river, its bulb was quickly covered with a thin crust of ice, which defended it so much from the cold subsisting in the atmosphere,

that it did not sink two degrees in ten minutes; whereas, when it was wiped dry after immersion in water, it sunk above  $20^{\circ}$  in a less space of time: this circumstance shews that ice doth not transmit cold, and is explained by the experiments of M. *Richmann*, who hath established it as a principle, that metallic substances are far more quickly affected in their dimensions by the transitions from heat to cold, and the contrary, than any other bodies yet known.

Being desirous of observing the effect of this extraordinary degree of cold upon various saline solutions, I hastened to my laboratory, where I happened to have a great many solutions of salts corked up in quart bottles; the bottles were not all full, but the solutions were perfectly saturated; the state in which I found them

them is expressed in the following table.

Frozen wholly

Alum

Cream of tartar

Arsenic

Corros. sublimate

Borax

Nitre

Frozen nearly

Green vitriol

Blue vitriol

Rochelle salt

Glauber's salt genuine

White vitriol, a few glacial spicula

Wholly fluid

Sea salt

Sal gemmæ

Sal ammoniac

Volatile

Volatile alkaline salt

Fixt alkali per deliq.

Epsom salts

Glauber's salts } Lymington.

These experiments agree upon the whole very well with those of Professor *Braunius*, related in the *Petersburgh Commentaries* for 1763: for, though his saturated solutions of *Epsom* salts, and of fixt alkali, had begun to freeze in a less degree of cold, yet it is probable that his *Epsom* salts might have been different from those manufactured at *Lymington*, and the solution of his fixt alkali not so well saturated as that which is made per deliquium.

During the same frost, I endeavoured to find out the powers, by which different salts, when they are dissolved in water, resist congelation.

tion. With this view I dissolved equal weights of salts, equally dry, in equal quantities of water, and exposed the solutions, when they were arrived at the same degree of heat, in vessels of equal and similar figures to the same freezing atmosphere; and accurately marking the times in which they began to freeze, I found them observing the following order: first alum, then Rochelle salt, green vitriol, sugar refined, white vitriol, vitriolated tartar, Glauber's salt, mineral fixt alkali, nitre, blue vitriol, volatile alkali, sal ammoniac, last of all, sea salt. These experiments were repeated once or twice with some attention; yet I would not be thought to propose the order in which I have arranged the several salts, as wholly to be relied on. It were to be wished, that a sufficient



sufficient number of experiments were accurately made upon this subject; some general truths relative to metallic earths, and alkaline neutral salts, would probably be obtained therefrom, which, however unimportant in themselves, might serve, upon some occasion or other, as connecting links, to extend the chain of our ideas. By this comparison of equal quantities of different salts dissolved in equal quantities of water, we might be enabled to speak with as much precision, concerning the powers by which they resist congelation, as we do concerning those by which they resist putrefaction. I know not whether it may not be thought too curious a remark to observe, that the ocean is impregnated with that species of salt which resists congelation with the greatest power,  
and

and in such a quantity as tends not to preserve entire, but to accelerate the dissolution of the numberless animals which are daily dying in it. *Beccher*, it hath been asserted, was acquainted with this property of common salt; but he seems only to speak of it as a far less efficacious antiseptic than sugar; at least, the honour of ascertaining the proportion in which it acts as a septic undoubtedly belongs to *Sir John Pringle*; for *Beccher*, in his *Physica Subterranea*, lib. I. sect. v. cap. 1. where he is speaking of this matter, says,  
 “ *Quod nimius salis usus corpus pu-*  
 “ *trescere faciat, sicut modicus a pu-*  
 “ *tredine præservat.*”

To a table exhibiting the relative powers of neutral salts in resisting congelation, another might be usefully added, denoting the powers of all the known acids and alkalis  
 when

when diluted to a given density; as also of vinous spirits, from highly rectified spirits of wine to water impregnated with the minutest quantity of spirit. Not but that it may be conjectured *a priori*, that in this last case the resistance to congelation would be directly as the quantity of spirit contained in given quantities of water. I made an experiment of this kind with sea salt; in equal quantities of water were dissolved quantities of sea salt, increasing in the arithmetical progression, 0, 5, 10, 15, 20, &c.; the times in which the solutions began to freeze, reckoning from the time in which simple water began, increased accurately in the same progression: hence it may be inferred, that, in salt of the same kind, the resistance to congelation is in the direct simple proportion of the quantity

quantity of salt dissolved; this conclusion cannot be extended to salts of different kinds, since water saturated with sea salt is more difficultly congealed than when saturated with various other salts, which it dissolves in greater quantities.





## ESSAY V.

*Account of an Experiment made with  
a Thermometer, whose Bulb was  
painted black, and exposed to the  
direct Rays of the Sun.*

**D**URING the hot weather, which we had in the latter end of June and the beginning of July, 1772, I made an experiment at *Cambridge*, which I then thought no more of, but which an accident hath brought to my mind again; and I now venture to relate an account of it, in hopes that some philosophical friend will take the trouble of prosecuting it. I exposed the bulb of an excellent thermometer to the direct rays of the sun, when the sky was perfectly free from clouds: the

mercury rose to  $108^{\circ}$  of *Fahrenheit's* scale, and continued stationary. A fancy struck me, to give the bulb a black covering; this was easily effected by a camel's hair pencil and *Indian* ink; the mercury sunk a few degrees during the application of the coating, and the evaporation of the water; but presently after rose to  $118^{\circ}$ , or  $10^{\circ}$  in consequence of the black coat with which I had covered that part of the bulb which was exposed to the sun. If the bulbs of several corresponding thermometers were painted of different colours, and exposed at the same time to the sun, for a given period, some conjectures, respecting the disposition of the several primary colours for receiving and retaining heat, might be formed, which could not fail of being, in some degree, interesting.

TRACT VI

*Plan of Chemical Lectures, 1771.*

INTRODUCTION.

**H**ISTORY of chemistry, and  
of alchemy.

Of the elements of chemistry commonly received—Earth, air, fire, water.

Conjectures concerning the mutual convertibility of chemical elements.

Of the solidity, fluidity, fixity, and volatility of bodies in different degrees of heat.

Conjectures concerning the formation and nature of the atmosphere.

Calcination, sublimation, evaporation, distillation *per ascensum*, *per retortam*, *per descensum*, explained and exemplified.

Of the different degrees of heat required for the conducting of different operations: the terms *venter equinus*, *balneum maris vel mariæ*, *balneum vaporis*, *capella vacua*, *balneum cinerum*, *arenæ*, *limaturæ ferri*, explained.

The heat of boiling homogeneous fluids in open vessels, shewn to be incapable of increase from an increase of fire.

The heat of boiling homogeneous fluids shewn to be greater or less, within certain limits, in proportion to the augmentation or diminution of the pressure of the atmosphere, or other elastic fluid upon their surface.

A fluid contained in a vessel exposed

posed to the action of boiling water for any length of time, does not acquire the heat of boiling water without it come in immediate contact with it.

The heat of boiling oil ascertained, and the use of a *balneum olei* illustrated.

The structure and use of simple, reverberatory, melting, cupelling and other furnaces explained.

The nature of the inflammable principle, *pabulum ignis*, or phlogiston, inquired into from the phenomena attending the combustion of vegetable oil, animal fat, vinous spirits, charcoal, and metallic substances.

The earth obtained from the combustion of the phlogiston of metallic substances converted into its primary metallic appearance by the



addition of phlogiston; exemplified in the reduction of the flowers of zinc by charcoal, and of minium by charcoal, by animal fat, and by iron filings.---The identity of phlogiston inferred from the preceding experiments.

Definition, and general division of saline substances into acid, alkaline, and neutral salts.

Acid salts distinguished commonly from alkaline and neutral salts by their taste; by effervescing with calcareous earths; and by changing the blue colour of syrup of violets, and other blue vegetable infusions into a red.

Alkaline salts distinguished from neutral salts by taste; by effervescing with acids; and by changing the blue colour of syrup of violets into a green.

A neutral

A neutral salt made from a mixture of an acid and an alkali.---The term saturation explained.

The vegetable fixed alkali extracted from the ashes of charcoal by solution and filtration ; and from tartar by combustion---Pearl-ash---Pot-ash---Salt of tartar.

Salt of tartar rendered liquid by exposure to the air, improperly in that state called oil of tartar *per deliquium*.

Quantity of water attracted from the air by a given quantity of salt of tartar, in a given time, estimated by experiment.

The mineral fixed alkali extracted from the ashes of the plant kali, jointed glass-wort, marsh samphire, or *salicornia* of *Linnaeus*, and from sea tangle, &c. by solution and fil-

tration, and its difference from the vegetable fixed alkali shewn.

Volatile and fixed alkalis distinguished from each other by the smell, and by the different colours produced in mixing them with a solution of corrosive sublimate. --- Uncertainty of this criterion remarked.

## OF MINERALS.

### *Of the Pyrites and green Vitriol.*

Natural history of the pyrites.

Sulphureo - ferrugineous pyritæ from the chalk pits of *Cherry-hinton* analysed by distillation---Sulphur---Ferrugineous residuum: method of assaying any particular species of the pyrites for sulphur.

Analysis of sulphur by combustion  
--- Phlogiston --- Volatile sulphureous acid: method of obtaining the  
acid

acid of sulphur at *Battersea*, and in other places.

Iron-pyritæ defulphurated by roasting.

Green vitriol extracted from the defulphurated iron-pyritæ by elixation and cryftallization: method of affaying any particular species of the pyrites for green vitriol.

Iron-filings, fulphur, and water kneaded together: Intumescence---Incalescence---Incension of the mixture.

Conjectures concerning the origin of subterraneous fires and volcanos founded upon the preceding experiment.

Green vitriol extracted from the residuum of the preceding experiment.

Of the weathering, or spontaneous decomposition and simultaneous vitriolization, of the pyrites.

Various species of the pyrites exhibited in a vitriolizing state.

Green vitriol extracted from vitriolized pyritæ.

Account of the principal green vitriol works in *Great Britain*.

Native green vitriol---*German*---*English*.

Method of purifying green vitriol from copper, and of discovering whether it contains copper.

Green vitriol calcined to a white, yellow, and red colour.

Calcined green vitriol analysed by distillation---vitriolic acid---ferrugineous *residuum* or colcothar.

*Of the vitriolic Acid and its Combination with Water, with fixed, and with volatile alkaline Salts.*

The vitriolic acid of the preceding process concentrated, or rectified



by distillation: Weak acid, commonly called spirit of vitriol---Residuum, strong acid, improperly called oil of vitriol.

Degree of heat arising from the mixture of oil of vitriol and water observed by a thermometer: proportions producing a *maximum* of heat ascertained by experiment.

Quantity of water attracted from the air by a given quantity of oil of vitriol, in a given time, estimated by experiment: use of oil of vitriol as an hygrometer.

Specific gravity of oil of vitriol determined.

Equal bulks of oil of vitriol and water mixed together: specific gravity of the mixture not equal to the mean specific gravity of the two fluids.

Dr. *Hook's* experiment, concerning  
ing

ing the penetration of dimensions in the mixture of oil of vitriol and water, considered.

Vitriolic acid not absorbed into the pores of water, as *Musschenbroek* and others have supposed.

Acid of vitriol combined with the fixed alkaline salt of tartar---*Tartarus vitriolatus* made after *Tachenius's* manner---General properties of vitriolated tartar.

*Sir Isaac Newton's* theory concerning chemical attraction stated and explained---*Geoffroy's*, *Gellert's*, and other tables of affinity explained.

Acid of vitriol combined with the fixed alkaline salt of kelp---*Glauber's sal mirabilis*---General properties of Glauber's salt.

Acid of vitriol combined with volatiie alkali---*Sal ammoniacus secretus*

*cretus Glauberi* ; general properties of this salt.

*Of the Combination of the vitriolic  
Acid with Earths.*

Acid of vitriol combined with earth of *sal catharticus amarus*---  
History of *Epsom* salts.

Acid of vitriol combined with argillaceous earths---Alum.

Natural history of aluminous ores.

*Schistus aluminosus* crude, and calcined, from Yorkshire and Lancashire.

Account of the principal alum works in England.

Method of assaying aluminous mineræ.

Alum calcined---*Alumen ustum*.

*Alumen ustum* dissolved in water and crystallized.

Analysis

Analysis of alum by distillation---  
Vitriolic acid---Residuum.

Analysis of alum by precipitation  
with fixed alkaline salt of tartar---  
Vitriolated tartar---Earth of alum.

Account of the experiments of  
*Marggraf* and *Macquer* upon the  
earth of alum.

Nature of argillaceous earths---  
Conjectures concerning the identity  
of argillaceous and vitrifiable earths.

Acid of vitriol combined with  
vitrifiable earth.

Acid of vitriol combined with  
calcareous earth.

Natural history of plaster-stone,  
alabaster, gypsum, selenites.

Specimens of plaster-stone from  
*Montmartre* near *Paris*, from *Corn-*  
*wall*, *Derbyshire*, *Westmoreland*, &c.

Specimens of rhomboidal selenites  
from *Shotover Hill* in *Oxfordshire*, of  
striated

striated gypsum from *Derbyshire*, of  
*gypsum phosphorescens* from *Bononia*,  
 &c.

Gypseous earth analysed by boiling it with salt of tartar -- Vitriolated tartar and calcareous earth obtained therefrom.

History of the discovery of the  
*Bononian phosphorus* — Experiments therewith.

Artificial Bononian phosphorus made from calcined oyster shells and flowers of sulphur after Mr. *Canton's* method --- Account of his experiments therewith.

*Of the Combination of the vitriolic Acid with Phlogiston, Spirits of Wine, and Oils.*

Acid of vitriol combined with phlogiston—Sulphur.

Natural



Natural history of sulphur.

*Sulphur nativum, pellucidum et opacum*, from *Solfatara* near *Naples*.

*Sulphur nativum pulverulentum aquis efflorescens*, from the baths of *Aix-la-Chapelle*.

Account of the different methods of preparing crude sulphur in *Germany, Saxony, &c.*

Sulphur purified by sublimation—Flowers of sulphur—Sulphur flag.

Sulphur crystallized.

Spirit of sulphur *per campanam*—Various ways of obtaining it.

Acid of vitriol changed into a volatile sulphureous acid, by the addition of phlogiston in a state of dissipation.

Volatile sulphureous acid combined with the fixed alkaline salt of tartar---*Stahl's* sulphureous salt.

Sulphureous salt of *Stahl* changed  
into

into vitriolated tartar by simple exposure to the air, or by the addition of oil of vitriol.

Sulphur united with fixed alkaline salt by fusion---*Hepar sulphuris*.

*Hepar sulphuris* changed into vitriolated tartar by the dissipation of the phlogiston---Analysis of sulphur.

Vitriolated tartar changed into *hepar sulphuris* by the addition of phlogiston---Synthesis of sulphur.

The proportion of the constituent parts of sulphur deduced from the two preceding experiments of Stahl.

*Hepar sulphuris* digested in rectified spirits of wine---*Tinctura sulphuris*.

Sulphur rendered soluble in water, by boiling it with fixed alkaline *lixivia*, or with lime-water.

Sulphur precipitated from the preceding solutions by weak spirits

of vitriol—*Lac sulphuris*—*Sulphur præcipitatum*.

Sulphur united with volatile alkaline spirits by distilling it with sal ammoniac and lime—*Tinctura sulphuris volatilis*.

Action of water and acids upon sulphur examined.

Remarks upon *M. le Comte de Lauragais*' Method of uniting Sulphur with Spirits of Wine.

Sulphur dissolved in oil of turpentine.....*Balsamum sulphuris terebinthinatum*.

Sulphur dissolved in oil of olives.....*Balsamum sulphuris simplex*.

History of the Discovery of *Homburg's pyrophorus*.

Various pyrophori made from alum, Glauber's salt, &c. calcined in conjunction with matters containing phlogiston.

Oil of vitriol mixed with rectified spirits of wine....Phænomena attending the commixtion....The mixture distilled....Æther of *Frobenius*....Sulphureous acid....Oil of spirits of wine....Artificial resin....Sulphur....Caput mortuum.

Specific gravity of æther determined.

Cold produced by the evaporation of æther....Of spirits of wine....Of alkaline salts, &c.

Application of this principle of producing cold by evaporation, to the cooling of liquors, &c. in hot climates.

Phænomena attending the combustion of æther.

Miscibility of æther with water, in certain proportions, proved.

The characteristics of æther, as

distinguished from spirits of wine, and from essential oils.

Oil of vitriol mixed with oil of turpentine....Artificial resin resulting therefrom: Proportions of the ingredients which, cæteris paribus, produce the most solid resin.

The preceding artificial resin distilled --- Sulphureous acid .... Oil .... Sulphur....Caput mortuum.

### *Of Nitre.*

Account of the different methods of making nitre in the East-Indies, and in Europe.

Of the medium quantity of nitre annually imported into Great Britain from the East-Indies, and exported to various parts of Europe.

Crude nitre extracted from nitrous earths.

Crude



Crude East-India nitre purified from sea salt, and calcareous earth.

*Nitre from America.*

Account of the attempts to make nitre in England.

Analysis of the mother water of nitre.

History of the medicinal application of *magnesia alba*.

Nitre analyzed by distilling it with calcined vitriol.....Acid of nitre or *aqua fortis*.....Residuum.

Residuum of the preceding process analyzed.....Vitriolated tartar..... Ferrugineous earth.

Acid of nitre procured by distilling nitre with sand, clay, alum, &c.

Fuming acid of nitre procured by distilling nitre with oil of vitriol.....Residuum examined.

Fuming acid of nitre purified by

distilling it with nitre. Test of the purity of acid of nitre.

Fuming acid of nitre mixed with water....Change of colour observed....Degree of heat ascertained.

Fuming acid of nitre mixed with snow, and with powdered ice....Degree of cold ascertained.

Fuming acid of nitre mixed with the crystals of kelp....Degree of heat observed.

Diluted acid of nitre mixed with crystals of kelp....Degree of cold observed.

Fuming acid of nitre simple, and combined with oil of vitriol mixed with various oils....Inflammation produced thereby....Residua.

Enumeration of the various oils which have been observed to take fire, to effervesce without taking fire, and which neither effervesce or take

take fire, when mixed with the fuming acid of nitre.

Acid of nitre dulcified with rectified spirits of wine, by distillation and digestion.

Nitrous æther made by spontaneous distillation, and by digestion.

Nitre alkalized by fusion.

Nitre alkalized by charcoal.....  
*Clyffus* of nitre.

*Volatile alkali* in a concrete form separated from the *clyffus* of nitre.

Nitre detonated with tartar in various proportions.....White flux.....  
Black flux.

Nitre deflagrated with sulphur—  
*Sal polychrestus*—*Sal prunellæ*.

*Pulvis fulminans* made from nitre, salt of tartar and sulphur....Explosion of *pulvis fulminans*.

History of the invention of gunpowder.

Gunpowder made from nitre, sulphur, and charcoal---Account of the different proportions of the ingredients used in different countries, and in different works in England. ---Best proportions ascertained.

Method of extracting nitre from damaged gunpowder at Woolwich, &c.

Gunpowder decomposed----The three constituent parts exhibited separate---Method of detecting frauds used in the composition of gunpowder explained.

Acid of nitre combined with calcareous earth---Calcareous nitre---*Phosphorus Balduini*.

Acid of nitre combined with argillaceous earth---Aluminous nitre.

Acid of nitre combined with the vegetable fixed alkali---Regenerated nitre.

Acid

Acid of nitre combined with the mineral fixed alkali---Quadrangular or cubic nitre.

Acid of nitre combined with volatile alkali---Nitrous sal ammoniac.

Of the use of nitre in agriculture.

The use of snow in fertilizing the ground, shewn not to depend upon the nitre it is generally supposed to contain.

### *Of Sea Salt.*

Natural history of sea salt---*Sal marinus, fontanus, fossilis.*

History of the discovery of fossil salt in England.

Account of the method of preparing sea salt in different parts of the world.

Of the different antiseptic powers  
of



of sea salt according to the different processes by which it is prepared.

Of the bittern of sea salt.

Of the method by which Epsom salts, common Glauber's salts, and magnesia, are extracted from the bittern of sea salt at Lymington, and other places.

Method of distinguishing the genuine sal mirabilis Glauberi from the counterfeit of the shops.

Analysis of sea water, attempted.

Comte *Marfigli's* artificial sea water.

*M. de Francheville's* opinion, concerning the saltiness of the sea, examined.

Mr. *Boyle's* opinion, concerning the uniform saltiness of the sea at different depths, examined.

Account of various attempts to edulcorate sea water.

Of

Of Mr. *Irving's* late attempt.

Of the tests of the purity of distilled sea water.

Of the phosphoric quality of sea water in particular places, and at particular times in the same place.

Mr. *Canton's* experiments concerning the cause of the luminousness of sea water.

Account of other opinions concerning the same subject.

Sea salt dissolved and crystallized.

Decrepitation and fusion of sea salt.

Sea salt analyzed by distilling it with acid of vitriol after Glauber's manner --- Fuming spirit of salt --- Residuum.

The residuum of the preceding process analyzed, and the fixed alkaline basis of sea salt obtained therefrom after Marggraf's method.

*Glauber's*

*Glauber's* fuming spirit of salt purified by distilling it with sea salt.

Sea salt distilled with vitriol, clay, &c.---Acid of sea salt---Residua.

Acid of sea salt separated from its alkaline basis by acid of nitre.

Acid of sea salt combined with calcareous earth---*Phosphorus Hombergi*.

Acid of sea salt combined with argillaceous earth---Muriatic alum.

Acid of sea salt combined with earth of *sal catharticus amarus*.

Acid of sea salt combined with fixed alkali of tartar---*Sal febrifugus Sylvii*.

Acid of sea salt combined with alkali of kelp---Sea salt regenerated.

Acid of sea salt combined with volatile alkali---Artificial sal ammoniac.

Acid

Acid of sea salt dulcified by distillation with spirits of wine.

Marine æther made after the *Marquis de Courtanvaux's* manner.

*Aqua regia* made by mixing together acid of sea salt and acid of nitre.

*Aqua regia* made by dissolving sea salt or sal ammoniac in acid of nitre  
---Its difference from the preceding *aqua regia*, remarked.

Of sea salt as a condiment, and as a manure.

### *Of Sal Ammoniac.*

Natural history of sal ammoniac.

Method of making sal ammoniac in *Egypt*.

Method of making sal ammoniac in *Europe*.

*Sal ammoniacus glebosus* from Solfaterra.

Sal ammoniac purified by sublimation.

Sal ammoniac purified by crystallization.

Sal ammoniac dissolved in spirits of wine.

Sal ammoniac deflagrated with nitre.

Sal ammoniac analysed by distilling it with the acid of vitriol, and of nitre---Marine acid---Residua.

Sal ammoniac analysed by distilling it with fixed alkali---Volatile alkali---Residuum.

The volatile alkaline spirit of sal ammoniac procured by distilling it with quicklime---Caustic spirit of sal ammoniac.

The residuum of the process examined---*Oleum calcis*.

Volatile alkaline salt spirit procured



cured by distilling sal ammoniac with chalk---Mild spirit.

Caustic spirit of sal ammoniac mixed with acids, with spirits of wine, lime-water, calcareous nitre, &c.

Mild spirit of sal ammoniac mixed with acids, with spirits of wine, lime-water, calcareous nitre, &c.

*Eau de luce* made.

Degree of cold, produced during the solution of sal ammoniac in water, observed by a thermometer.

Equal quantities of water of different temperatures saturated with sal ammoniac, and the degrees of cold severally produced during the saturation, remarked.

Of the greatest possible degree of cold which can be produced in water by the solution of sal ammoniac.

Of

Of the use of fal ammoniac in various arts.

*Of Borax.*

Natural history of *tincal*, or crude borax.

Borax vitrified.

Glass of borax dissolved in water, and crytallized.

*Sal sedativus Hombergi* separated from borax by the acids of vitriol, nitre, sea salt, and vinegar, and procured by sublimation and crytallization.

The residua examined, and the mineral fixed alkali separated therefrom.

Borax regenerated by combining together fal sedative and mineral alkali.

Sal sedative dissolved in spirits of wine,

wine, the green colour of the flame observed.

Of copper supposed to be contained in borax.

Account of the attempts to make artificial borax in *England*.

Of the mechanic uses of borax.

*Of Mineral Earths, crude and calcined.*

Distillation of siliceous, calcareous, argillaceous, and gypseous earths.

Account of the experiments lately made at *Paris* by M. *Darcet*, and others, concerning the infusibility and volatility of diamonds in a great degree of heat.

Vitrification of a mixture of earths, separately unvitriifiable in a given degree of heat.

Glass made from a mixture of alkaline salts and powdered flints.

History of the invention of glafs.

Of the method of making and polishing plate glafs in France, &c.

Siliceous earths rendered soluble in water by means of alkalis---*Liquor silicum.*

Of European and Asiatic porcelain, and their specific difference.

Account of the methods of making the white and yellow Staffordshire ware.

Calcareous earths converted into lime by calcination.

Calcareous earths converted into lime by solution and precipitation.

Lime converted into calcareous earth.

Dr. *Black's* theory of lime explained.

The quantity of fixed air contained in alkalis, and calcareous earths, and separable by solution, estimated,

estimated by the Honourable *Hen. Cavendish*.

The loss of weight sustained by calcareous earths during calcination estimated by experiment, and shewn to correspond with the quantity of fixed air, separated therefrom by solution.

Of the solubility of lime in water.

Of the pellicle of lime-water, and of the excess of its weight above the weight of the lime dissolved.

Is the smallest quantity of lime wholly soluble in the largest quantity of water, without undergoing a fresh calcination?

Of marle.

Of the use of lime, marle, &c. in agriculture.

*Of Arsenic.*

Natural history of white pyrites,



orpiment, realgar, cobalt ores, and other mineral substances affording arsenic.

Method of procuring arsenic in Saxony, called from its powdery appearance, *farina arsenicalis*.

*Farina arsenicalis* purified, and changed into white crystalline arsenic, by being mixed with pot-ash and sublimed.

*Farina arsenicalis* mixed with the sulphur of sulphureous pyrites, and changed into yellow or red crystalline arsenic by sublimation.

Arsenic dissolved in oil of olives, in oil of turpentine, in a solution of fixed alkali, in rectified spirits of wine, in aqua fortis, in acid of sea salt, in aqua regia, in oil of vitriol, in vinegar, and in water.

Arsenic and nitre distilled together---Acid of nitre---Residuum.

*Macquer's*

*Macquer's* neutral arsenical salt extracted from the residuum.

Nitre and arsenic fused together in open vessels---Fume---Residuum called nitre fixed by arsenic.

Arsenic combined with phlogiston, and sublimed into a metallic appearance, commonly called *regulus* of arsenic.

## OF METALLIC SUBSTANCES IN GENERAL.

### *Of Mercury in a fluid State.*

Natural history of mercury and of cinnabar.

Mercury extracted from earths or stones with which it is mixed, by simple lotion, and by distillation without addition.

Mercury extracted from minerals,

in which it is mineralized, by distillation with addition.

Method of assaying mercurial minerals, and of discovering whether any particular mineral contains mercury.

Methods of purifying mercury.

Mercury changed into a black powder by long continued trituration.

Mercury changed into a red powder by calcination---*Mercurius calcinatus*---*Mercurius præcipitatus per se*.

Mercury boiled with water.

Mercury revived, from the powders obtained by trituration, and calcination, by simple distillation.

Account of *Boerhaave's* experiments relative to the unchangeableness of mercury, by the processes of digestion, and distillation.

Account of Professor *Braunius's* experiments, relative to the conversion of mercury into a solid malleable metal, at *Petersburgh*, by an artificial cold resulting from the solution of snow in the fuming spirit of nitre.

Of the degree of heat of boiling mercury, and of the limits within which mercury may be used as a thermometer.

Mercury triturated with turpentine, with lard, with sugar, &c.---Mercurial plasters, ointments, pills.

Mercury dissolved in acid of nitre ---The solution diluted with distilled water, *aqua mercurialis*.

The solution of mercury in acid of nitre crystallized.

The same inspissated---*Calx mercurii*.

The inspissated mass, or crystallized

lized salt, calcined to a red colour---

*Mercurius præcipitatus ruber.*

Mercurius præcipitatus ruber dulcified by spirit of wine---*Mercurius corallinus*---*Arcanum corallinum.*

Mercury precipitated from its solution in acid of nitre by copper.

Mercury corroded into a saline mass by oil of vitriol.

The preceding saline mass partly dissolved, principally changed into an insipid, indissoluble, yellow powder, by frequent ablution in warm water---*Mercurius emeticus flavus*---*Mercurii præcipitatum flavum*---*Turpethum minerale.*

Mercury precipitated, from the washings of turpeth mineral, by alkalis.

Washings of turpeth mineral inspissated, and deliquiated---*Oleum mercurii.*

Mercury



Mercury united by sublimation with the acid of sea salt; corrosive sublimate made from a mixture of unwashed turpeth mineral and sea salt.

Corrosive sublimate made from crystals of mercury in the nitrous acid and sea salt.

Corrosive sublimate made from crude mercury, nitre, calcined vitriol, and sea salt.

Corrosive sublimate rendered mild and insipid, by trituration with a sufficient quantity of crude mercury and subsequent sublimations---*Mercurius dulcis sublimatus*---*Calomelas*---*Aquila alba*---*Panaceæ mercurialis*---*Draco mitigatus*, &c.

Specific gravities of corrosive sublimate and calomel, determined.

Corrosive sublimate dissolved in water, and crystallized.

Corrosive

Corrosive sublimate dissolved in spirits of wine.

Mercury precipitated from a solution of corrosive sublimate in water by fixed alkalis---*Mercurius præcipitatus fuscus*, by volatile alkali---*Mercurius præcipitatus dulcis*, by lime water---*Aqua phagedenica*.

Mercury precipitated from its solution in acid of nitre by the acid of sea salt, or by any neutral salt containing the acid of sea salt---*Mercurius præcipitatus albus*.

Mercury precipitated from its solution in acid of nitre by the acid of vitriol, or any neutral salt containing the acid of vitriol---Turpeth mineral.

Mercury dissolved in the vegetable acids, native, and fermented, and in fixed, and volatile alkalis, after *Marggraf's* method.

Account of *M. le Comte de la Garaye's* tincture of mercury in spirits of wine.

Mercury united with sulphur by trituration, and by fusion---*Æthiops mineral*.

A mixture of sulphur and mercury sublimed---Factitious cinnabar.

Factitious cinnabar levigated---*Vermillion*.

Method of discovering whether vermillion be adulterated with red lead.

Mercury revived by distilling cinnabar with iron-filings.

Mercury united with volatile tincture of sulphur, and with hepar sulphuris.

#### OF SEMIMETALS.

*Of Antimony, and Regulus of Antimony.*

Natural history of antimony, and other ores of *regulus* of antimony.

Crude

Crude antimony separated from earthy and stony impurities by eliquation, or distillation per descensum — *Morsuli restaurantes Kunckelii.*

Crude antimony digested with aqua regia, solution of the metallic, and separation of the sulphureous part effected thereby.

Crude antimony calcined to an ash-coloured calx.

Calcined antimony vitrified.

Glass of antimony digested with aqua regia, sulphur sometimes separated thereby --- Differences observable in the fusibility, colour, pellucidity, and solubility of glass of antimony in wines, and other menstruums, according to the different degrees of calcination used in preparing it.

*Regulus* of antimony prepared, by fusing the calx, or glass of antimony with

with charcoal, soap, or other phlogistic matters.

*Regulus* of antimony prepared, by fusing crude antimony with iron, with lead, with copper, &c.

*Regulus* of antimony prepared, by fusing crude antimony with tartar and nitre.

Chief mechanic uses of regulus of antimony noticed.

Regulus of antimony volatilized by a strong fire---Flowers of regulus of antimony.

Method of reducing flowers of regulus of antimony.

Action of acids upon regulus of antimony, examined.

Regulus of antimony combined with the marine acid by distilling antimony and corrosive sublimate together---*Causticum antimoniale*, or butter of antimony.

Regulus



Regulus of antimony precipitated from the marine acid, by diluting butter of antimony with water---*Pulvis algaroth*---*Mercurius vitæ*.

Regulus of antimony precipitated from the water used in the preceding process, commonly called *spiritus vitrioli philosophicus* by an alkali.

*Bezoard* mineral prepared, by repeated abstractions of the acid of nitre from butter of antimony---*Spiritus bezoardicus*.

Antimony and nitre mixed together in the proportion of 2 to 1, and deflagrated---*Crocus antimonii mitior*.

Antimony and nitre mixed together in equal parts, and deflagrated---*Crocus antimonii*---*Hepar antimonii*, edulcorated---*Crocus metallorum*.

Antimony and nitre mixed together in the proportion of 1 to 2, deflagrated and edulcorated---*Emeticum mite antimonii*.

Antimony

Antimony and nitre mixed together in the proportion of 1 to 3, deflagrated andedulcorated---*Calx antimonii*---*Antimonium diaphoreticum dulce*.

Different chemical properties of the preceding, and other similar combinations of nitre and antimony, explained; general account of their medical powers deduced therefrom.

Washings of diaphoretic antimony considered --- *Materia perlata*, or *Boerhaave's sulphur fixatum stibii* precipitated therefrom.

Regulus of antimony reduced to calx, similar to diaphoretic antimony, by deflagration with nitre, called *cerusse of antimony*.

Antimony combined with fixed alkali by boiling them together---*Kermes mineral* spontaneously precipitated from the solution.

*Tinctura antimonii* made by digesting *hepar antimonii* in spirits of wine.

*Vinum*

*Vinum antimoniale sive emeticum*, made by digesting crocus antimonii, or glass of antimony in mountain wine.

*Tartarus emeticus* made by boiling glass, or crocus of antimony with cream of tartar.

*Tartarus emeticus* made, after *Macquer's* manner, by combining pulvis algaroth and cream of tartar.

Of the medical virtues of antimonial preparations in general, and the cause of the variable and uncertain effects of particular preparations explained.

### *Of Zaffre and Regulus of Cobalt.*

Method of making *zaffre* in Saxony.

The *zaffre* of the shops dissolved in all the mineral acids.

The difference of the colour of the

the solution of zaffre in weak and strong acid of sea salt observed.

The *tawny* colour of zaffre dissolved in weak spirit of salt, changed into a *green* by heating the solution.

Zaffre changed into a blue glass by vitrification, called *smalt*.

Method of preparing from the blue glass of zaffre, an impalpable powder, called in that state *azure*, *enamel blue*, *powder blue*.

Of *lapis lazuli*, and the pigment called *ultramarine blue* prepared therefrom, and its difference from the *azure* prepared from zaffre.

*Regulus of cobalt* procured from zaffre or *smalts*, when melted in conjunction with matters containing phlogiston.

General properties of *regulus of cobalt* enumerated.

Account of the manufacturing of  
smalts in England.

*Orpiment* and quicklime digested  
together with water---*Liquor vini*  
*probatorius*.

Use of the preceding liquor in  
detecting adulterations of wine by  
*saccharum Saturni*, shewn from the  
different colours of the precipitates  
attending its mixture with genuine  
and adulterated wine.

Experiments with the aforesaid  
liquor as a sympathetic ink.

### *Of Nickel.*

Nickel not soluble in acid of vi-  
triol, with difficulty in acid of sea  
salt, readily by acid of nitre into a  
green colour.

Nickel precipitated from acid of  
nitre by a fixed alkali into a greenish  
powder.



Nickel compared with regulus of cobalt.

Experiments with sympathetic inks from solutions of nickel and cobalt.

### *Of Bismuth.*

Natural history of bismuth.

Bismuth sublimed into yellowish flowers by a strong fire.

Bismuth changed into an ash-coloured powder by calcination.

Calx of Bismuth vitrified.

Vitrified calx of bismuth reduced by the addition of phlogiston.

Bismuth dissolved in acid of nitre.

Solution of bismuth in acid of nitre crystallized.

Bismuth precipitated from the solution in acid of nitre by the affusion of water --- *Magistery of bismuth* --- *Blanc de fard*.

Bismuth precipitated from the

washings of the magistery by a fixed alkali.

Bismuth and mercury melted together---Amalgam.

Bismuth, lead, and mercury, melted together---Method of falsifying quicksilver---Method of detecting the adulteration of quicksilver.

Bismuth not miscible by fusion with nickel.

### *Of Zinc.*

Natural history of *lapis calaminaris*, *black jack*, and other ores of zinc.

Zinc procured by distilling lapis calaminaris with charcoal.

Account of the method of making English zinc at the copper works near Bristol, and its difference from Indian zinc shewn.

Zinc calcined in a gentle fire, inflamed in a strong fire---Flowers  
of

of zinc, or *lana philosophorum* separated during the combustion of zinc.

Flowers of zinc vitrified.

Flowers of zinc reduced in close vessels.

Flowers of zinc dissolved in all the acids.

Zinc deflagrated with nitre.

Zinc dissolved in acid of vitriol  
---Nature of the black *flocculi* separated during the solution.

Solution of zinc in acid of vitriol crystallized---white vitriol.

Method of discovering whether white vitriol contains copper.

Difference between English and Goslarian white vitriol.

Zinc dissolved in acid of nitre.

Solution of zinc in acid of nitre crystallized.

Zinc dissolved in the concentrated acid of sea salt, and in the aqueous acid

acid of vitriol---Inflammable air separated during the solution in each menstruum.

The quantity, and specific gravity of the inflammable air separated from zinc by solution, estimated by the Hon. *Henry Cavendish*.

Zinc not acted upon by sulphur, or liver of sulphur---Purified thereby from all other metallic substances.

Zinc not miscible by fusion with bismuth.

## OF METALS.

### *Of Lead.*

Natural history of lead ores.

Account of the two different methods of extracting lead from its ore, as practised in Derbyshire.

Lead extracted from its ore---  
Method of assaying simple lead ores.

Lead in fusion partly volatilized,  
chiefly

chiefly converted into a gray calx, called *plumbum ustum*, or calcined lead.

Plumbum ustum melted in a strong fire--- *Litharge*.

Account of the method of making red lead from plumbum ustum, as practised in Derbyshire.

Account of the method of making red lead from litharge, as practised in Flintshire.

Remarks concerning the quantity, and cause of the increase of weight, gained by the conversion of lead into minium.

Glasses of lead made from minium simple, and mixed with vitrifiable earth in different proportions.

Artificial ores, perfectly resembling some kinds of natural ores of lead, made from an union of lead and sulphur.



Of *black lead* or *wadd*.

Method of distinguishing the factitious from the true black lead.

Black lead exposed to a strong fire in close vessels---Fixity remarked.

Black lead exposed to a strong fire in open vessels---Loss of weight remarked.

Calcined black lead attracted by the magnet.

Lead corroded into a white calx by the vapour of vinegar, called *cerusse*, or white lead.

Account of the method of manufacturing white lead at Holywell, and other places, and of the increase of weight gained by the lead.

White lead, minium, or litharge, dissolved in distilled vinegar, and crystallized---*Sugar of lead*.

Crude lead, white lead, minium,  
or

or litharge dissolved in oil of olives  
 ---Common *diachylon* plaster.

Method of discovering whether  
 oil of olives be adulterated, by means  
 of lead, with rapeseed, or other ex-  
 pressed oils.

Lead separated, from its solution  
 in oils, by vinegar.

Lead dissolved in acid of nitre,  
 and crystallized.

Lead precipitated from acid of  
 nitre by acid of vitriol, or any neu-  
 tral salt containing acid of vitriol;  
 by acid of sea salt, or any neutral  
 salt containing acid of sea salt.

Lead distilled to dryness with oil  
 of vitriol. --Sulphureous acid---Sul-  
 phur--Saline residuum.

Sulphur procured instantaneously  
 by pouring oil of vitriol upon lead  
 in fusion, and collecting the vapour.

Lead or minium distilled with salt  
 ammoniac

ammoniac---Volatile alkaline spirit  
 ---Volatile alkaline salt---Residuum,  
 or a combination of the acid of sea  
 salt with lead, called *plumbum cor-*  
*neum*.

*Plumbum corneum* fused.

*Plumbum corneum* dissolved in  
 water, and crystallized.

Lead and mercury melted toge-  
 ther in different proportions—Amal-  
 gams of various consistencies.

### *Of Copper.*

Natural history of copper.

Account of the processes used in  
 extracting copper from its ore, at  
 Ecton, Macclesfield, Cheadle, &c.

*Regulus* and *scoria* of the first, se-  
 cond, third, and fourth fusion of  
 copper ore examined, and the reason  
 of their differences explained.

Copper

Copper combined with sulphur by stratification and cementation---*Æsustum*.

Copper combined with sulphur by fusion---Artificial ore of copper.

Copper combined with arsenic by fusion---*White copper*.

Of Chinese white copper, improperly called *tutenag*, and its difference from the preceding white copper shewn.

Copper changed into *brass*, by cementing and fusing copper in conjunction with calcined calamine and charcoal.

Copper changed into brass, by substituting, in the preceding process, calcined black jack for calamine.

Brass changed into copper, by dissipating the zinc or metallic part of the calamine, in a strong fire.

The

The increase of weight, gained by the copper in being changed into brass, estimated.

Copper melted with zinc---*Pinchbeck*.

Difference between pinchbeck and brass observed, and the reason explained.

Copper melted with tin in various proportions --- *Bell metal* --- *Bronze*, &c.

Equal parts of copper and tin melted together; their mutual penetration and increase of specific gravity observed.

Copper dissolved in oil of vitriol.

Solution of copper in oil of vitriol crystallized---*Blue vitriol*.

Copper precipitated from a solution of blue vitriol by iron---*Cuprum præcipitatum*, called *ziment copper*.

Account of the cement or ziment waters



waters at Newfolin Hungary, Arklow in Ireland, in Anglesea, &c. and of the methods of procuring copper from them.

Copper dissolved in acid of nitre, and crystallized.

Copper precipitated from acid of nitre by chalk---*Verditer blue*.

Copper dissolved in acid of sea salt, and crystallized.

Crystals of copper, in the acids of sea salt, and nitre, when dissolved in spirits of wine, communicate a green colour to the flame.

Copper dissolved in oils, in vegetable acids, in fixed, and volatile alkalis, in neutral salts, &c.

Account of the method of making *verdigrise* at Montpellier, and in England.

Various mechanical applications of *verdigrise* enumerated.

Verdigrise

Verdigrise dissolved, in part, in distilled vinegar.

Solution of verdigrise in distilled vinegar crystallized, improperly called *viride æris distillatum*.

Crystals of verdigrise distilled--- Concentrated acid of vinegar, called *acetum radicum*---Cupreous residuum.

Acetum radicum mixed with rectified spirits of wine, and acetous æther made after the manner of *M. le Comte de Lauragais*.

### *Of Iron.*

Natural history of iron.

Account of the processes used in extracting iron from its ores in different parts of England and Wales; and of the attempts to make pig iron by coke and charred peat.

Method

Method of converting pig iron  
into bar iron.

Of the tenacity of iron wire.

Iron converted into steel.

Steel converted into iron.

Steel hardened, and rendered brittle and elastic.

Of tempering of steel.

Iron deprived of its phlogiston by  
various ways---Different kinds of  
*crocus Martis*.

Natural history of *ochres*.

Red and yellow ochres converted  
into iron by the addition of phlogiston.

Iron deprived of its phlogiston by  
deflagration with nitre.

Iron combined with sulphur.

Iron dissolved in acid of vitriol---  
*Sol Martis*.

Iron dissolved in acid of sea salt.

The inflammable air arising from  
iron

iron during the two preceding solutions collected and inflamed.

Of fulminating damp in mines.

Method of freeing the coal-pits at Whitehaven from inflammable air described.

Iron dissolved in acid of nitre, elastic but not an inflammable air produced thereby.

History of the discovery of the method of making *Prussian blue*.

Prussian blue made by precipitating a solution of green vitriol with an alkali saturated with phlogiston.

The colouring matter of Prussian blue extracted by an alkali.

Iron precipitated from any of its acid solvents into a blue powder by a fixed alkali, saturated with the colouring matter of Prussian blue.

Iron precipitated from any of its acid solvents into a black powder by

by a decoction of galls or other astringent vegetables.

Nature of ink and of the black dye, and the difference between them explained.

*Beccher's experimentum ferriferum* considered.

Iron shewn to exist in common sand, in coloured clays, in the ashes of vegetables, in the ashes obtained from the blood, urine, and flesh of animals.

Vegetable ashes melted into a green or blue glass, according to the violence of the fire.

Iron filings or colcothar of vitriol mixed with sal ammoniac and sublimed—*Flores martiales*—Residuum.

Residuum deliquiated—*Lixivium Martis*—*Oleum ferri*.

Flowers of iron digested with spi-



rits of wine—*Tinctura florum martialis*.

Iron precipitated from its solution in acid of nitre by fixed alkali—*Stahl's alkaline tincture of iron*.

Iron combined with cream of tartar by grinding them together—*Rotuli martiales*—*Mars solubilis*; by boiling, *tartarus chalybeatus*, *tinctura styptica Helvetii*.

Iron dissolved in Rhenish wine—*Vinum chalybeatum*.

### Of Tin.

Natural history of tin.

Of the processes of stamping, budding, and trunking used in *Cornwall* for preparing tin ore for fusion.

Of the *magnetiren* used in some parts of Germany.

Tin melted and granulated.

Tin rendered hard and sonorous  
by

by being melted in conjunction with regulus of antimony, with zinc, with bismuth, &c.

Of *pewter* and its different kinds.

Of different metallic mixtures which melting with less heat than the metals to which they are applied, constitute folders of various kinds.

Method of manufacturing *tin plates* in England and Germany, and of tinning copper vessels.

Tin calcined singly and in conjunction with lead—*Putty*.

Calces of lead and tin melted with calcined flints, or other vitrifiable earths, and alkaline salts, in various proportions—*white enamels*.

White enamels converted into different colours, by the addition of metallic calces, and applied upon English and Indian porcelain.

Pastes and artificial precious stones

made, and their difference from coloured enamels explained.

Tin amalgamated with quicksilver, and the amalgam mixed with sulphur and sal ammoniac, and sublimed—Residuum called *aurum mosaicum* or *musicum*.

Tin dissolved in aqua regia—Different consistences of the solutions.

Tin dissolved in acid of nitre.

Use of the preceding solutions of tin in precipitating the colouring matter of cochineal.

Woollen and linen boiled in cochineal precipitated by tin—Reason of the different dyes explained by *Macquer*.

Inflammable air separated from tin during its solution in acid of vitriol and acid of sea salt.

Account of *Marggraf's* experiments upon the solubility of tin in vegetable

vegetable acids, native and fermented.

Tin amalgamated with quicksilver, and the amalgam distilled with corrosive sublimate—*Liquor fumans Libavii*—Butter of tin—Revivified mercury.

Looking glass silvered by amalgamating mercury and tin.

Tin, bismuth, and lead melted together, and mixed with mercury—Method of silvering concave glass vessels with the mixture.

### *Of Silver.*

Natural history of silver.

Account of the method of separating native silver from the stones or earths in which it is imbedded, by amalgamation with mercury; as practised at *Potosi* and other Spanish

silver mines in America, and at *Kungsborg* in Norway.

Account of the method of separating silver when mineralized with sulphurated lead, as practised in Flintshire, and in Northumberland.

Cardiganshire lead ores assayed for silver.

Silver purified from semimetals, and imperfect metals, by cupellation with lead.

Silver purified from such minute portions of copper as escape cupellation, by fusion with nitre and borax.

Silver separated from  $\frac{1}{3}$ , or any less part of its weight of gold by solution in acid of nitre—Quartation or departure.

Silver recovered from its solution in acid of nitre by precipitation with copper.

Solution



Solution of silver in acid of nitre crystallized.

Crystals of silver melted—*Lunar caustic*.

Silver precipitated from acid of nitre, by acid of vitriol, or by any neutral salt containing acid of vitriol.

Silver distilled to dryness with acid of vitriol—Sulphureous acid—Saline residuum.

Saline residuum dissolved in water, and crystallized.

Silver precipitated from acid of nitre, by acid of sea salt, or by any neutral salt containing it—*Luna cornea*.

*Marggraf's* method of obtaining silver absolutely pure by the reduction of luna cornea.

Silver precipitated from its solution in acid of nitre by fixed alkali.

Precipitated silver dissolved in vegetable acids, in volatile, and phlogisticated fixed alkalis, according to *Marggraf's* method.

Pure silver made harder by being melted with copper in the proportion of 37 to 3—*Standard silver of England.*

Silver precipitated from acid of nitre, largely diluted with water, by means of mercury—*Arbor Diana.*

Silver combined with sulphur into an artificial ore resembling the *minera argenti vitrea.*

### *Of Gold.*

Natural history of gold.

Method of separating native gold from sands, earths, &c. by amalgamation with quicksilver.

Method of extracting gold when mineralized, or when so mixed with sulphur

fulphur by means of other metals as to escape the action of quicksilver and aqua regia.

Gold soluble in aqua regia, but not in acid of nitre.

Silver soluble in acid of nitre, but not in aqua regia.

Method of purifying gold from all metallic substances by solution in aqua regia, and precipitation with green vitriol.

Method of separating a minute portion of gold from a large quantity of silver, by melting the mixture with sulphur, as practised at Ram-melsberg.

Gold precipitated from its solution in aqua regia made with acid of nitre and acid of sea salt, by volatile alkali—*Aurum fulminans*.

Aurum fulminans deprived of its fulminative power by oil of vitriol,  
by

by fusion with sulphur, by fixed alkali, and in part by ablution with water.

Gold precipitated from its solution in aqua regia, when largely diluted with water, by plates of tin, or by a solution of tin in the same menstruum — *Purple magistery of Cassius.*

Glass changed into an artificial ruby by being melted with Cassius' purple magistery.

Gold extracted from its solution in aqua regia, and kept suspended in æther.

Method of separating gold from gilt copper.

Gold precipitated from its solution in aqua regia by fixed alkali.

Precipitated gold dissolved by the same menstruums as precipitated silver.

Gold distilled to dryness with the acid of vitriol, with the acid of sea salt, and with the acid of nitre—Insoluble in these menstrooms.

Gold dissolved in hepar sulphuris.

Pure gold hardened by being melted with copper, or with an admixture of copper and silver, in the proportion of 22 to 2—*Standard gold of England.*

Gold amalgamated with mercury—Methods of gilding and separating gold from gilt works.

#### OF MINERAL WATERS IN GENERAL, AND THEIR VARIOUS IMPREGNA- TIONS.

Different methods of assaying mineral waters, and their imperfections.

Of *thermæ*, or hot mineral waters,  
and



and the different conjectures concerning the cause of the heat.

Account of Dr. *Brownrigg's* experiments on the fixed air contained in *Spa* water.

M. *Lane's* experiments concerning the suspension of iron in water, by means of fixed air discharged either from fermenting, or effervescing mixtures.

### *Of Bituminous Substances:*

Natural history of bituminous substances.

Newcastle coal distilled—Phlegm—Acid—Air—Oil—Caput mortuum.

Air discharged from Newcastle coal by distillation, collected, and shewn to be inflammable, and to retain its elasticity and inflammability for several days.

Peat

Peat from the isle of *Ely* distilled  
—Phlegm—Acid—Oil—Alkali—  
Caput mortuum.

Amber dissolved in spirits of wine.

Amber precipitated from its solution in spirits of wine by water.

Amber distilled—Phlegm—Acid spirit—Volatile acid salt—Oil—  
Caput mortuum.

Method of rectifying oil of amber.

Method of purifying salt of amber.

Amber varnish made by different methods.

## OF VEGETABLES.

Of vegetable juices spontaneously extravasated, or exuding upon incision.

### *Of liquid Resins or Balsams.*

*Venice* turpentine distilled without addition with the heat of boiling water

water—Acidulated phlegm—Colourless essential oil, commonly called æthereal spirit of turpentine—*Resinous residuum*.

*The residuum* of the preceding process distilled with a degree of heat exceeding that of boiling water—Acid—Yellow oil—Residuum called *colophony*.

*Colophony* distilled to dryness—Acid—Reddish oil, called by some, balsam of turpentine—Caput mortuum.

*Common* turpentine distilled with water—Essential oil, vulgarly called spirit of turpentine—Residuum—*Terebintbina cocta*, or common rosin.

Turpentine dissolved in spirits of wine, and precipitated therefrom by water.

Of *tar* and *pitch*, and the method of procuring them.

Tar dissolved in part in water.

Of lamp black, and the method of obtaining it.

Balsam of *capivi* distilled *balneo arenæ*—Acid—Yellow oil—Blue or green oil—Caput mortuum.

Of balsam of *Gilead*, balsam of *Peru*, balsam of *Tolu*, liquid amber, &c.

### *Of solid Resins.*

*Benzoin* dissolved in spirits of wine, and precipitated therefrom by water—Virgin's milk.

Acid phlegm and essential salt, commonly called flowers of benzoin, obtained from benzoin by sublimation.

Essential salt obtained from benzoin by elixation with water and crystallization.

Flowers

Flowers of benzoine dissolved in water, and in spirits of wine.

The residuum from the sublimation of the flowers of benzoine distilled—Acid—Oil of different consistences—Caput mortuum.

Elemi — Mastic — Copal — Dragon's blood, and other solid resins dissolved in spirits of wine and oils.

Different kinds of varnishes made, and applied upon wood and metals.

### *Of Camphor.*

Native camphor.

Rough camphor refined by sublimation.

Rough camphor refined by solution in spirits of wine.

Camphorated spirits of wine inflamed.

Camphor dissolved in acid of nitre, and in acid of vitriol.

Camphor



Camphor separated from spirits of wine, and from mineral acids by the addition of water.

### *Of Gums.*

Gum arabic, gum tragacanth, gums from pear trees, plum trees, apricot trees, &c. dissolved in water—Mucilages.

Gums dissolved in water, and precipitated therefrom by spirits of wine.

Gums distinguished from resins principally by their solubility in water, and insolubility in spirits of wine, and by their being neither fusible, nor inflammable in fire.

Gum arabic distilled—Acid—Oil—Volatile alkali—Caput mortuum.

### *Of Gummy Resins.*

Gum *ammoniac* dissolved in spirits of wine.

Gum ammoniac dissolved in water.

Of *assa fætida*, myrrh, frankincense,  
and other gummy resins.

OF VEGETABLE JUICES OBTAINED BY  
TRITURATION, AND EXPRESSION.

*Of essential Salts of Plants.*

Native aqueous juices expressed  
and clarified.

Native aqueous juices evaporated  
and crystallized—Essential salts.

Of neutral salts contained in ve-  
getables.

History of sugar, and of the me-  
thod of preparing it.

Brown or gray Muscovade—Me-  
lasses, or treacle.

Method of refining sugar.

Sugar dissolved in water and crys-  
tallized—*Saccharum candum, et crys-  
tallinum.*

Sugar

Sugar dissolved in rectified spirits of wine, and crystallized.

Refined sugar distilled — Acid — Oil — Air — Caput mortuum.

Of saccharine juices obtainable from maple trees, birch trees, sycamore trees, &c. by tapping; from fruits and roots of various kinds, by solution in spirits of wine; from the spontaneous exudations of the *fraxinus rotundifolia*, and other trees producing *manna*; and from various flowers affording honey to the bee.

Native juices of vegetables inspissated to different consistences — Liquid or solid extracts by expression.

Of *aloes*, *opium*, *acacia vera*, and other solid extracts by expression.

### *Of expressed Oils.*

Oils obtained by expression from

linseed, mustard seed, ripe olives, almonds, walnuts, &c.

Expressed oils distinguished principally from essential oils, in not being soluble in spirits of wine, nor volatile in the heat of boiling water, and in having scarce either taste or smell.

Method of impregnating expressed oils with the odorous principle of violets, lilies, roses, &c.---Various perfumes.

Oil of olives distilled --- Phlegmatic acid---Oil---Fixed oil---Caput mortuum.

Of the rancidity of expressed oils.

Expressed oils suspended in water by means of mucilages---Emulsions ---Milky juices of plants.

Of the combination of oils with fixed alkali.

Fixed alkali deprived of its fixed  
air

air by quicklime—Caustic alkali—  
Soap lees.

Soap lees inspissated—*Cauterium  
potentiale, lapis infernalis.*

Oil of olives, oil of turpentine,  
train oil, tallow, &c. dissolved in  
soap lees—Soaps of various kinds.

Solution of soap in distilled water,  
and in spirits of wine.

METHOD OF ANALYZING VEGETA-  
BLES FURTHER EXPLAINED, BY IN-  
FUSION, AND DECOCTION IN VARI-  
-OUS MENSTRUUMS.

*Carduus benedictus* infused in cold  
water.

*Carduus benedictus* boiled in wa-  
ter.

Peruvian bark infused in cold wa-  
ter.

Peruvian bark boiled in water.



Jalap digested with spirits of wine  
—Tincture of jalap—Residuum.

The residuum of the preceding process boiled with water and inspissated—Aqueous extract of jalap.

Refin of jalap precipitated from tincture of jalap by water.

Method of obtaining the resinous and gummy parts of vegetables, and of making spirituous, aqueous, and mixt extracts.

Aqueous decoction of red Saunders.

Spirituous decoction of red Saunders.

Aqueous decoction of Brazil wood.

Spirituous decoction of Brazil wood.

Aqueous decoction of alkanet root.

Spirituous decoction of alkanet root.

Red Saunders digested in oil of turpentine.

Alkanet

Alkanet root digested in oil of turpentine.

Archel boiled in water, in oils, in acids, in spirits of wine, in fixed alkalis, and in volatile alkalis.

The colouring matter of some vegetables precipitated by alum, solutions of tin, &c.—*Lakes*.

Various experiments relative to the production, change, and recovery of colours; by different saline additions to coloured vegetable infusions.

Of dying in general.

METHOD OF ANALYZING VEGETABLES  
BY DISTILLATION, EXEMPLIFIED IN  
VARIOUS INSTANCES, AND VARIOUS  
DEGREES OF HEAT.

Mint, thyme, rosemary, lavender, or other aromatic plants distilled with a heat *less* than that of boiling

water and *without* addition—*Spiritus rector*, or odorous principle.

The same plants distilled *with* the addition of water, and with the *heat* of boiling water—Essential oils—Aromatic or simple distilled waters.

Of the different weights, colours, and consistences, of essential oils.

Essential oils by expression from oranges, citrons, &c.

Method of obtaining them in Italy.

Essential oils soluble in spirits of wine.

Rosemary tops, lavender flowers, &c. distilled with spirits of wine—Spirit of rosemary, spirit of lavender, &c. more commonly called Hungary water, lavender water, &c.

Essential oil of rosemary, and of lavender, precipitated from Hungary  
water

water and lavender water, by the affusion of water.

Of distilled spirituous waters.

Rosemary, &c. after the extraction of their essential oil, distilled to dryness—Phlegm—Acid—Empyreumatic oil—Caput mortuum.

Method of making charcoal explained.

Charcoal not acted upon by water, acids, alkalis, vinous spirits, or oils.

Charcoal decomposed by burning—Phlogiston—Residuum.

Quantity of residuum from a given weight of charcoal estimated.

Fixed alkaline salt and earth obtained from the residuum.

Of the method of manufacturing and depurating pot-ash.

Of the difference between the mineral fixed alkali, or *natron* of the ancients, and the vegetable fixed alkali.

*Ana'ysis*

*Analysis of Woods.*

Oak distilled *balneo Mariæ* —  
Phlegm—Residuum.

Residuum distilled — Phlegm —  
Acid air—Oil lighter and heavier  
than the acid—Caput mortuum.

Air from oak not destructive of  
flame, but inflammable after passing  
through water, and through fixed  
alkaline lixivia, and retaining its  
inflammability for several days.

Of the different quantities of char-  
coal, of liquid contents, and of fixed  
air obtained from equal weights of  
oak, box, hazel, willow, and other  
woods by distillation.

Of the best kinds of charcoal re-  
quisite for the making of gunpow-  
der, fluxing of metals, &c.

Volatile alkali disengaged from  
the acid of oak by fixed alkali.



Acid of box-wood rectified.

Rectified acid of box saturated with vegetable and mineral fixed alkalis—Nature of neutral salts from the distilled acids of vegetables.

Analysis of the *Tetradynamia* of Linnæus.

Mustard seed, pepper wort, &c. distilled with the heat of boiling water—Phlegm sapid and odorous, but neither manifestly acid nor alkaline.

Mustard seed, &c. distilled with a degree of heat superior to that of boiling water—Volatile alkali, acid, air, oil, caput mortuum.

### *Of Soot.*

Wood foot distilled—Acid—Volatile alkali—Empyreumatic oil—  
Salt

Sal ammoniac — Caput mortuum,  
yielding fixed alkali.

*Of Wax.*

Wax distilled — Acid — Oil —  
Congealed oil — Caput mortuum.

Congealed oil or butter of wax,  
rectified — Acid — Yellow oil — Fat  
brown residuum.

Methods of bleaching yellow wax,  
and of colouring bleached wax.

OF FERMENTATION IN GENERAL.

*Of the vinous Fermentation.*

History and use of *malting* as preparatory to the fermentation of farinaceous feeds.

Equal weights of barley, rye, wheat, oats, beans, peas, converted into malt, and after decoction  
for

for the same time in equal quantities of water exposed to fermentation—  
*Ale* of different sorts.

The medium heat of fermenting wort estimated by the thermometer, and shewn to be equal to the medium heat of an animal body.

The air generated during the vinous fermentation shewn to be deleterious to animal life and to flame.

The specific gravity of air, generated by vinous fermentation proved by the Hon. *Henry Cavendish* to be greater than that of common air, and to be equal to that separable from marble by solution, or about 511 times lighter than water, when common air is supposed 800 times lighter.

Equal weights of raisins, refined sugar, brown sugar, treacle mixed with equal quantities of water and  
 fermented

fermented—*Wines* of different kinds.

Ale distilled—Malt spirits—residuum.

Wine distilled--Brandy--Residuum.

*Potatoes* fermented and distilled—*Potatoe brandy*.

Of the methods of making malt spirits, brandies, rums, arracks, and the origin of their different odours and flavours explained.

Malt spirits, brandy, &c. distilled—*Alcohol*, or rectified spirits of wine—Acidulated phlegm.

Of the identity of alcohol from whatever fermented liquor it is distilled.

*Of proof spirit.*

Usual methods of estimating the strength of brandies, rums, &c. and their imperfections.

Alcohol and water mixed together, the bulk of the mixture shewn

to

to be considerably *less* than the sum of the separate bulks.

Method of judging accurately concerning the strength of spirituous liquors pointed out.

Of the arrack or *cosmos* prepared by the *Calmuck Tartars* from mare's milk.

Method of obtaining white and red *tartar*.

Tartar purified—Cream or crystals of tartar.

Tartar distilled—Acid—Air—Oil—Volatile alkali—Caput mortuum.

Fixed alkaline salt extracted from the caput mortuum of distilled tartar without burning it.

Crystals of tartar combined with absorbent earths.

Crystals of tartar combined with the fixed alkali of tartar—*Sal vegetabilis, tartarus tartarizatus*.

Crystals



Crystals of tartar combined with the fixed alkali—*Sal polychrestus de Saignette*—*Rochelle salt*.

Crystals of tartar combined with volatile alkali.

OF THE ACETOUS FERMENTATION,  
OR THE SPONTANEOUS CONVERSION OF ALES AND WINES INTO  
ALEGARS AND VINEGARS.

Method of making vinegars, and of discovering whether they are adulterated with oil of vitriol.

Vinegar distilled—Phlegm—Acid—Extract.

Method of discovering whether vinegar be depraved by lead.

Extract of vinegar distilled—Acid—Empyreumatic oil—Volatile alkaline salt, and spirit—Caput mortuum.

Vinegar

Vinegar concentrated by *freezing* the phlegmatic part.

Distilled vinegar combined with absorbent earth.

Distilled vinegar combined with the fixed alkali of tartar—*Sal Diureticus*—*Terra foliata tartari*.

Distilled vinegar combined with the mineral fixed alkali, and crystallized.

Distilled vinegar combined with volatile alkali—*Spiritus mindereri*—Acetous sal ammoniac.

Combinations of the acid of tartar with the vegetable and fixed alkalis, decomposed by the acid of vinegar.

Difference between the acid of tartar and that of vinegar.

*Of the putrefactive fermentation of  
vegetables.*

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OF ANIMALS.

General analysis of animal fluids  
exemplified in the analysis of milk,  
blood, urine, and whites of eggs.

*Of Milk.*

Cows milk distilled *balneo mariæ*  
— Phlegm transparent, colourless,  
insipid—Unctuous saline residuum.

Asses milk distilled *balneo mariæ*  
— Phlegm—Residuum,

Proportion of phlegm separable  
from equal weights of cows milk  
and asses milk by distillation B. M.  
ascertained.

Equal weights of cows milk,  
goats milk, woman's milk, asses  
milk,

milk, evaporated to dryness—Proportion of the residuums, and of the saline and earthy matter contained in them.

Residuum from the distillation of milk B. M. distilled---Acid---Empyreumatic oil ---Volatile alkali—Caput mortuum, containing fixed alkali.

Milk spontaneously separated into cream and skim-milk.

Cream resolved into butter—Curd—Whey.

Skim-milk resolved into whey—Curd—Butter.

Butter distilled—Acid—Oil—Caput mortuum.

Curd distilled—Alkali volatile in a fluid and concrete form....Fetid oil—Caput mortuum.

Whey evaporated and crystallized—*Sugar of milk*—*Sea salt*.

Milk not coagulable by the heat of boiling water.

Milk coagulable by acids, by alkalis, by vinous spirits, by some neutral salts earthy and metallic.

### *Of Blood.*

Blood examined by a microscope—Transparent fluid—Red globules of various sizes.

Blood warm from the vein distilled balneo mariæ—colourless, insipid phlegm—Residuum.

Of the quantity of phlegm contained in the blood of different animals, and separable therefrom by the heat of boiling water.

Phlegm, impregnated with volatile alkali, obtained from blood by the heat of a boiling fixed alkaline lixivium.

Blood



Blood exsiccated by the heat of the sun.

Blood exsiccated by the heat of the sun, or by distillation B. M. not subject to putrefaction.

Exsiccated blood distilled—Volatile alkaline spirit and salt—Air—Empyreumatic oil — Caput mortuum.

Blood spontaneously resolved, by exposure to the air, into a fluid and coagulated part---*Serum*---*Crassamentum*.

Account of Mr. *Hewson's* experiments, relative to the cause of the spontaneous coagulation of blood when taken out of an animal body.

Blood prevented from spontaneous coagulation by sea salt, and other neutral salts.

The *crassamentum* resolved, by ablu-  
tion, into a white fibrous part,  
u 3 called

called by some the coagulable lymph, not soluble in water, and a red colouring part, called the red globules, reckoned soluble in water.

The fibrous part or coagulable lymph distilled.

—The red globular part distilled.

The serum coagulated by boiling water, by acids and by vinous spirits.

*Of Urine.*

Fresh Urine gives no marks of containing either acid or alkaline salts.

Fresh human urine distilled B. M.  
—Colourless phlegm with an urinous smell—Residuum.

Residuum distilled—Volatile alkali in a fluid and concrete form—Oil—Sal ammoniac—Caput mortuum, yielding sea salt by elixation, and fixed alkali by calcination.

Horses

Horses urine distilled—phlegm—  
Volatile alkaline spirit—Oil—Caput  
mortuum, yielding fixed alkali with-  
out calcination, and sea salt by elix-  
ation.

Human urine evaporated and crys-  
tallized—Fusible, essential, native,  
microcosmic, phosphoric salt of urine  
—Sal ammoniac—Sea salt.

Horses urine, evaporated to a  
due consistency, does not yield a fu-  
sible salt, but a portion of sea salt  
and a magma incapable of crystal-  
lization.

Earth from the exsiccation of hu-  
man urine rendered white by calci-  
nation—Its habitude to fire and  
menstruums examined.

Account of Marggraf's experi-  
ments on the fusible salt of urine.

Volatile alkali separated from

fresh urine by fixed alkali and by lime.

### *Of Eggs.*

Whites of eggs coagulated nearly by the same degree of heat which coagulates the serum of blood.

Whites of eggs coagulable by acids and by spirits of wine—their use in clarification.

Whites of eggs distilled B. M. phlegm---Residuum.

Residuum distilled---Volatile alkali concrete and fluid---Empyreumatic oil---Caput mortuum.

Oil expressed from the yolks of eggs.

Of the essential oil, volatile acid, and expressed oil of ants.

*Of*

*Of Coral, &c.*

Volatile alkali procured from coral and sponges by distillation.

*Of Brains and Spermaceti.*

Contents of a human cranium distilled—Phlegm—Volatile alkali—Fetid oil—Caput mortuum.

*Of Fat.*

Suet distilled—Acid—Congealed oil—Caput mortuum.

*Of Bones and Horns.*

Horns rendered soft and flexible by boiling in water.

Ox horn, tortoise shell, &c. dissolved in acid of nitre.

Bones softened, and in part dissolved, by digestion in acids.

Earth of bones precipitated from acids by alkalis.

Gelatinous



Gelatinous and saline part extracted from hartshorn by boiling in water—Method of making glue—Portable soup—Isinglass—Size, &c.

Inert earth remaining after the extraction of gelly of hartshorn—*Cornu cervi philosophice calcinatum*.

Hartshorn distilled — phlegm — Volatile alkaline salt and spirit—Air — Empyreumatic oil — Caput mortuum.

Method of preparing volatile alkaline salt and spirit from bullocks bones, &c.

Animal oil dissolved in spirits of wine.

Animal oil rectified,—*Oleum animale Dippelii*.

### *History of Putrefaction.*

Caustic volatile alkali rendered mild

mild by the air discharged from putrescent bodies.

Volatile alkali separated with the heat of boiling water from putrid blood, pigeons dung, and putrid urine.

History of *Kunckel's* phosphorus.

Phosphorus made by distilling the extract of urine with *plumbum corneum* and charcoal, according to Marggraf's method.

Phosphorus made by distilling fusible salt of urine and charcoal together.

Method of rectifying phosphorus.

Several experiments with phosphorus.

Of other vegetables which yield a phosphorus by distillation.

Analysis of the *fæces alvinæ*.

Will be the in which it is  
VOLUME I  
Part of the  
History of the  
Metallurgy

History of the  
P. R. A. S. I. O.

extending of mine with  
**M**IRUM profecto et incredibile  
dictum est, quum late per un-  
versas Europae regiones tale dilata-  
tum Philosophia Naturalis ex quo  
patet eorum in Asiae Australis  
etiam in gentibus. Hinc reque-  
ritur, ut Societatem et Acad-  
emiam Lapidibus Commemoratam  
ad hoc tam difficile et arduum  
in hunc in ingenium eius Ausus et  
Progratus Cognationem locum  
potius completi, diffinitionem  
interdum inter Genua parcius et  
instructum cultu, tamis plerique  
petit, et Alchemicorum proprii de-  
lamenta, ab ipsa Legum doctrina  
auctoritate impetata. At in aliis re-

## TRACT VII.

*Institutiones Metallurgicæ.*

## P R Æ F A T I O.

**M**IRUM profecto et incredibile dictu est, quam late per universas Europæ regiones sese dilataverit Philosophia Naturalis, ex quo Peripateticorum atque Aristotelis Auctoritatem fregerit Baconus. Hinc æque singulorum, ac Societatum et Academiarum Laboribus Commentariisque, adeo jam diffusa est undique et disseminata, ut ingentes ejus Auctus et Progressus Cogitatione vix quisquam poterit complecti.

Jacebat interea *Chemia* parcius et infrequentius culta, sanis plerisque suspecta, et, Alchemicorum propter deliramenta, ab ipsa Legum nostrarum auctoritate improbata. At ut aliis re-

bus

*Chemia*

*Solum*

bus humanis ita etiam et Artium scientiis accidit, quæ nec in imo gradu neque in fastigio moram patiuntur.

Chemiam, quam haud ita pridem fuisse audivimus domi squalidam, fuligine infuscatam, et præ hominum ei deditorum pauperie pene ridiculam, foris per trivia misere vagantem, inhianti passim popello præstigias suas venditantem, a nemine fere non conculcatam et despectui habitam, nostris tandem temporibus sese alacrius erigentem, focillatam demum a Principibus, et a Philosophis ubique excultam auspicato satis admiramur. Eò quidem jam perducta est, ut quæ inter præcipuas plane doctrinas reponatur omnino digna sit, cum nec in Principiorum perspicuitate nec in Conclusionum pondere, sive philosophicos seu civiles respicias usus, ulli scientiarum cedat.

*Chemia* genere duplex est; corpora vel *resolvit* vel *componit*. Resolutio corporum iisdem, quibus ipsa eorum varietas specifica, terminis definitur; singulorum absoluta esse habetur cum ad *Elementa* vel principia homogenea, sive plura sint sive pauciora, perducatur.



catur.—Compositio corporum, Geometriæ instar, est infinita.

Partium Animalium figuram, nexum, et motum Anatomici; Vegetabilium fabricam Botanici; Fossilium situs atque habitus externos Mineralogici; non formas rerum sed mixtiones Chemicæ, perscrutantur.

Actiones Medicamentorum in corpora animalium tractat *Therapeutice*. Chemia autem quippe quæ resolvat mixta, resoluta conjungat, et varia quæ inde exoriantur phænomena dignoscant Therapeutices fit quasi anima: at cum infinitas simul aliorum corporum naturas retegat, et actiones mutuas investiget, ad universam potius Physicam, quam ad solam medicinam, tanquam ad suum ac proprium finem refertur.

Mechanica tum Physices tum Chemicæ sanioris fundamenta feliciter posuit *Newtonus*; cum de mutuis corporum Attractionibus, vel, ut Chemicæ loquuntur Affinitatibus, ex quibus omnis eorum Resolutio et Compositio pendet, in quæstionibus quibusdam suo de re optica libello adjectis quam sagacissime

gacissime disceptavit: fundamento jam  
posito molem extruxere paululum Re-  
centiores, felici admodum solertia; nec  
Ædificio Adminiculum nec forma  
deest: Fastigium Operi quod infinitum  
est, nulla ingeniorum sagacitas, nulla  
temporum diuturnitas unquam imponet.

In *Theoreticam* et *Præcticam* com-  
mode dividi potest Chæmia: hæc quæ  
Encheireses docet, Opificum est; illa  
quæ veritatem exquirat, Philosophorum.  
Veritatis indagatio omnis est Philoso-  
phiæ finis, hæc autem veritas inter  
physicos cognitione rerum experimentis  
eruenta continetur. Chæmia quoque  
infinitam propemodum experimento-  
rum, cum multis ante sæculis tum nostra  
etiam ætate institutorum, copiam com-  
plectitur, atque iisdem universa nititur.

Notiora tanquam ignota proferre, de-  
peculari aliena, antiqua undique cor-  
rasa tanquam nova ac propria vendi-  
tare, hominis est otio abutentis: At  
simulata a sinceris distinguere, dubia  
secernere a certis, indigestis nexum  
quendam conciliare et ordinem, ob-  
scuriora illuminare, infinitis modum  
statuere.

statuere, arduum sane sed nec inutile nec inhonestum est. Quod si magno cum discentium commodo, in aliis philosophiæ naturalis partibus absolutum hocce vidimus, quid obstat quo minus in Chemia quoque industriæ aliquid periclitemur? Hac mente Provinciam mihi ab Alma Matre demandatam, *Regis Ornatissimi* munificentia insignitam simul ac ditatam, quantum in me fuerit colui, et colam.

Lectores nihil hic reperient præter *Corporum Metallicorum Affectiones* cum alienis tum meis quibusdam experimentis enucleatas; quas in seriem Propositionum, brevem quidem at Lectionibus publicis explicandam et illustrandam redegi.

Opusculum hoc Tyronum gratia, currente calamo conscriptum, utcunque imperfectum et provectiorum notitia indignum, iis qui Chemicam a limine tantum salutant, vix erit inutile. Et cum nollem id extra Academiæ pomerium evagari aut publici fieri juris, erroris si quid aut incuria fuderit, aut ab ipsius operis obscuritate et difficultate irrepperit, id solita pro sua huma-

nitate condonent oro, qui hic loci  
 Chemiæ operam navarunt: iisque mei  
 adversum ipsos studii, pietatis erga  
 Academiam hoc qualecunque Testi-  
 monium, omni cum cultu et obser-  
 vantia, dico atque dedico.



## C A P. I.

*Definitiones.*

1 **C**ORPORA quæ ponderis decrementum in igne fortissimo non patiuntur *Fixa* vocantur, quæ patiuntur *Volatilia*; idque magis aut minus prout majori aut minori negotio partes eorum igne dissipantur.

2 *Partes volatiles* corporis, quæ fluidæ sunt et ignis vi in auras agantur, *evaporari* dicuntur; cum in vase clauso stillatim condensentur, *distillari*; *Solidæ* vero, cum sursum evectæ in forma solida condensentur, *sublimari* dicuntur: atque hæ vel *Sublimata* vel *Flores* vocantur, prout massam compactam, vel pulverem friabilem efficiunt.

3 Fluidum quodvis, solido affusum et ab eo distillatione separatum, dicitur ab eo *abstrahi*.

4 Cum partes aquosæ fluidi cujusvis compositi ab eo separantur, sive distillatione, sive corporum aquam vel phlegma



absorbentium interventu, sive congelatione, fluidum remanens *dephlegmari* vel *concentrari* dicitur.

5 Corpora, quæ vel culinari vel solari igne, sive ipsa ignis vi, sive aqua postea affundenda (ut fit in lapidibus calcareis) in Pulverem *fragilem, friabilem*, terræ similem fatiscunt, *calcinari* dicuntur: Pulvis iste *Calx* appellatur; præsertim si corpora sint ex regno minerali desumpta. Corpora quoque, cum in hujusmodi Pulverem Acidis corrosa dejiciantur, nonnunquam dici solent *in Calcem redigi*.

6 Corpora *via humida dissolvi* dicuntur, cum partes eorum fluido cuivis ita adjunguntur, ut unum quasi cum eo corpus visu homogeneum constituent, in eo suspensæ maneant, nec tamen id opacum vel turbidum reddunt.

7 Corpora sicca, quæ aeri exposita fiunt fluida, *deliquescere* vel *Deliquium pati* dicuntur.

8 Fluidum, quo corpora dissolvuntur, *Solvens* aut *Menstruum* vocatur.

9 Menstruum, cum de corpore solvendo nihil amplius in se recipere et sustinere potest, *saturari* dicitur.

10 Sepa-

10 Separatio corporis a menstruo quo solutum est, siue spontanea sit siue coacta, et siue fursum siue deorsum fiat, *Præcipitatio humida* dicitur; atque Materia ad imum dejecta, vel ad summum evecta, *Magisterium* vel *Præcipitatum* vocatur.

11 Cum partes corporis solidi adeo a se invicem vi ignis expandente separantur ut fiant fluidæ, corpus *fusum* vel *liquatum* esse dicitur.

12 Corpora heterogenea, quæ igne fusa, diversa particularum gravitate in duas partes interea separantur, *Præcipitationem siccam* vel *fusoriam* subire dicuntur. Pars illa quæ gravitate sua majori imum petit, *Regulus*, altera huic super incumbens *Scoria* appellatur.

13 *Eliquatio* est cum eo ignis gradu in quo altera Mineræ compositæ pars solida seu refractaria manet, altera fluit et ab illa separetur.

## C A P. II.

### *De Substantiis metallicis in genere.*

1 **S**UBSTANTIÆ metallicæ, arte metallurgica e mineris, educæ et fusione purgatæ, sunt corpora omnium  
x 3 longè

longè ponderosissima et (nisi subtilius partes dividantur) opacissima, aqua non solubilia, igne fusilia, at calore atmosphæræ terrestris (Mercurio excepto), non fluida, fulgore et nitore peculiari insignia. Hæ in duas classes, alteram Metallorum, alteram Semi-metallorum distribui solent.

2 Metalla, quæ hætenus cognita sunt, sex vulgo numerantur; Aurum, Argentum, Plumbum, Cuprum, Ferrum, et Stannum.

3 Semi-metalla habentur Platina (quæ metallis potius annumerari debeat), argentum vivum, Regulus Antimonii, Bismuthum, Zincum, Regulus Cobalti, et Nickel. Ad hæc ab omnibus fere, at temere forsan, adjungitur Regulus Arsenici.

4 Metalla a Semi-metallis majori sua malleabilitate præcipue distinguuntur.

5 Metalla fere dividuntur in duos ordines, metalla perfecta seu nobilia, et metalla imperfecta seu ignobilia. *Perfecta* habentur Aurum et Argentum; quibus adjungi debet Platina. Reliqua *imperfecta* esse deprehenduntur.

6 Metalla perfecta sunt, quæ in igne violentissimo et fixa manent, et calcinationem

nationem nullam patiuntur: *imperfecta*, quæ in igne et calcinationem patiuntur et partium dissipationem.

7 Omnes substantiæ metallicæ, exceptis forsan Auro, Platina, Argento et Argento vivo, si in igne aperto comburantur in calces convertuntur, quæ difficilius aut facilius vitrificationem admittunt prout calcinationem magis minusve perfectam subierint.

8 Calces et vitra metallica, cum Carbone, Olèo, Sevo, aliisve substantiis Phlogiston debito statu in se continentibus, præsertim in vase clauso, igni exposita in formam suam pristinam metallicam reducuntur, modo calcinationem nimiam non perpeffæ sunt; ipsa operatio vocatur *Reductio*.—Annon omnes Substantiæ Metallicæ constant ex terra vitrescente et substantia inflammabili? Quod si Phlogiston sit uniforme quiddam sibi ubicunque reperiatur simile, quæri potest 1<sup>mo</sup> num terræ metallicæ ab aliis omnibus terris vitrescentibus genere discrepant: et proinde, num Arte Chemica substantiæ Metallicæ generari queant: 2<sup>o</sup> utrum substantiarum Metallicarum dif-



ferentia oriatur a specifica quadam terrarum differentia; an a diversa proportionem et nexu quibus eadem terra cum Phlogisto conjungitur; an ab interpositione aliorum quorundam corporum: et proinde possint necne in se invicem transmutari?

9 Substantiæ Metallicæ, fusione inter se mistæ, raro magnitudinem illam habent quæ oriri debeat a magnitudinibus partium componentium simul sumptis. In quibusdam vero, ut in mixtura Stanni et Cupri decrementum magnitudinis et incrementum gravitatis specificæ sunt admodum notabilia. In aliis, ut cum Stannum et Zincum una colliquantur, tantum est magnitudinis incrementum, ut gravitas specifica sive densitas mixturæ minor sit gravitate specifica corporis levioris. In mixtura Cupri et Bismuthi ea fere deprehenditur densitas quæ secundum regulas communes hydrostaticas expectari debeat.

10 Quædam substantiæ Metallicæ, Ex. Gr. Aurum, Argentum, Cuprum, Plumbum, Stannum et Zincum, igne fusæ adeo magnitudine augeri, et specifica gravitate diminui dicuntur, ut  
frustulum



frustulum solidum ejusdem materiæ, cuilibet earundem cum fluidæ sint injectum, submergatur et in fundum subfidat; ut fit in Sevo, Cera et Resinīs liquefactis: Aliæ, ut Bismuthum Antimonium et præcipuè Ferrum, adeo diminui dicuntur magnitudine, ut solidum frustulum iis innatet, quemadmodum sulphur solidum sulphuri liquato aut Glacies aquæ innatat.

11 Plurimæ, fortasse omnes, Substantiæ Metallicæ igne satis fusæ et lentius postea frigefactæ, partium quandam regularem dispositionem vel *Crystallisationem* in superficie visibilem, sed in diversis generibus diversam, acquirere dicuntur.

12 Omnes Substantiæ Metallicæ calore dilatantur, frigore contrahuntur. Hæc magnitudinis mutatio, Pyrometro mensurata, minor esse observatur in Regulo Antimonii, et major in Zinco, quam in alia quavis Substantia Metallica.

13 Omnes Substantiæ Metallicæ citius et calescunt et refrigerantur quam aut Spiritus vini, aut Olea, aut alia ulla corpora: et hinc Thermometris  
et

et Pyrometris conficiendis adprimè aptæ sunt.

14 Substantiæ Metallicæ, nec in directâ nec in reciproca ratione densitatis, cohærentiæ, duritiei, nec in ratione quavis ex his quocunque modo composita, nec denique secundum ullam generalem legem huc usque repertam, calorem vel acquirunt vel amittunt.

15 Corpora Metallica fusa omne cum salibus et terris etiam metallicis respuunt connubium, superficiem convexam habent; præterquam quod si fusa sint in vasis metallicis ab horum lateribus partes contiguæ atrahuntur quasi, et superficiiei convexitas destruitur. Si cum sulphure liquifiant, omnia (præter Aurum et Zincum) in mineras, iis quæ e fodinis eruuntur similes, et ab iis vix distinguendas, convertuntur: cum Arsenico, omnia per fusionem uniuntur, et ab eo fragilia redduntur.

16 Metalla quædam, uti Ferrum, Cuprum et Argentum, quæ ignem ut fluant fortissimum postulant, sulphure addito citò liquefcunt: dum alia quædam,

dam, uti Plumbum et Stannum, per se satis fusilia, cum Sulphure conjuncta fiunt admodum refractaria.

### C A P. III.

#### *De Argento vivo sive Mercurio.*

1 **M**ERCURIUS est corpus metallicum tactu frigidum, omnium (Auro et Platina exceptis) ponderosissimum; eo propemodum caloris gradu quo aqua ebullit aut etiam minori, volatile; corpora, nisi metallica, non madefaciens; Atmosphæræ terrestres calore fluidum.

2 Mercurius frigore artificiali, a mistura spiritus nitri fumantis cum nive orto, in solidum mutari potest.

3 Mercurius frigore in solidum constrictus est metallum eximio nitore splendens; mallei patiens; duritie et sono quem reddit plumbo per simile.

4 Magnitudo Mercurii frigore fixi minor esse dicitur parte circiter 10<sup>a</sup> quam magnitudo ejusdem Mercurii ad ebullitionem calefacti.

5 Mer-

5 Mercurius, cum jamjam sit vel in calore ebulliturus, vel in frigore fluiditatem suam amissurus, celeriter ascendere et descendere observatur.

6 Mercurius purgatissimus, diu multumque agitato, converti potest aliqua ex parte, forsan omnis, in pollinem nigerrimum saporis acris, metallici ænei, qui igne valido, nullâ re additâ, distillatus fit *Mercurius vivus* vel *currens*.

7 Mercurius, in igne mitiori vase clauso diutius detentus, in pollinem nigrum antecedenti similem mutatur: in igne fortiori digestus quasi calcinatur in pulverem primo cineraceum, deinde flavescentem, tandem rubrum; qui improprie vocatur, *Mercurius præcipitatus per se*.

8 Mercurius calcinatus vel præcipitatus per se, ipso Mercurio ponderosior est et in igne fixior. Adaucto nihilominus calore dissipatur; remanente per parva quantitate pulveris fusci, qui vitro ustorio in vitrum fuscum mutatur: dum mercurius qui calcinationem non passus est, ab eo calore, nullo restante residuo, in auras pellitur.

9 Mer-



9 Mercurius quingenties amplius distillatus, singulis vicibus semper quidam pulveris rubri in retorta reliquit; at aliam non subiit mutationem.

10 Mercurius præcipitatus per se, in igne culinari, nullo addito Phlogisto, maxima ex parte reviviscit. Residuum igne fortissimo fixum est: fufum cum Borace, in massam friabilem vitrescentem vertitur; cum Plumbo cupellatum, prorsus evanescit.

11 Acidum Nitri mercurium facile dissolvit. Solutio evaporata, præbet Crystallos albas, acerrimas, longas, nonnunquam et tenues nitro similes: inspissata, in massam vertitur albam, salinam, admodum causticam, quæ æque ac crystalli igni in patella exposita fit pulvis, primo albus, deinde flavus, tandem dum calidus manet purpureus, sed frigescens ruberrimus; qui vocatur *Mercurius præcipitatus ruber*.

12 Acidum Vitrioli Mercurium vix dissolvit, nisi sit ebulliens et concentratum. Si distilletur, odorem sulphureum a Mercurio acquirit, et Mercurius simul corrosus fit massa salina,  
alba,



alba, quæ in igne violentiori colorem non mutat, aere non deliquescit, et aquam calidam affundendo partim in ea dissolvitur, partim mutatur in pulverem flavedinis eximiæ, qui fervida aqua sæpius ablutus fit insipidus; et vocatur *Mercurius emeticus flavus*, vel *Turpetum minerale*.

13 Acidum marinum in Mercurium non agit viâ humidâ; at in vapores resolutum, et ei per sublimationem variis modis conjunctum, salem crystallinum semipellucidum constituit; qui vocatur *Mercurius sublimatus corrosivus*, tunc viribus rodendi maximis pollens, cum proportio Acidi, respectu habito ad Mercurium, fit maxima.

14 Mercurius sublimatus, maximè corrosivus, cum ea quantitate Mercurii crudi tritus quæ sufficiat Acido marino perfectè saturando, et sublimatus fit opacus, aqua non solubilis, vis rodentis expers, et *Mercurius dulcis sublimatus* nuncupatur.

15 Acida vitriolica et marina iis qui Propositionibus 12<sup>a</sup> et 13<sup>a</sup> explicantur modis cum Mercurio uniuntur. Quòd si Acida hæc vel Solutio salis cujuslibet medii,

medii, in quo alterutrum continetur, in Mercurium Acido nitri solutum infundantur, Mercurius sese iis adjunget et pulveris albi forma præcipitabitur. Pulvis hic, si cum Acido vitriolico jungatur, fit *Turpethum minerale*; si ab Acido marino præcipitatio fiat, *Mercurius præcipitatus albus* vocatur, sublimato corrosivo vel dulci accedens prout sit vel non sit edulcoratus.

16 Mercurius sublimatus corrosivus, aqua solutus, ab Alkali fixo in fundum præcipitatur in forma pulveris rubri: ab aqua calcis præcipitatus fit flavus: ab Alkali volatili albus: a mistura Alkali fixi et Alkali volatilis paribus quantitativis albor nihil inquinatur.

17 Spiritus vini rectificatus, et ebulliens, suum pene pondus Sublimati corrosivi; ad gradum 16<sup>m</sup> Thermometri Reaumeri aut 68<sup>m</sup> Fahrenheitii calefactus, tres octavas ponderis sui partes, dissolvit.

18 Spiritus vini rectificatus, ad gradum 68<sup>m</sup> Thermometri Fahrenheitiani calefactus, et Sale Ammoniaco saturatus, Sublimati corrosivi tres quartas ponderis sui partes dissolvit: et proinde

vis ejus solvendi Sublimatum corrosivum Salis Ammoniaci additione duplicatur.

19 Aqua, cum ebulliat, dimidium suum pondus de sublimato corrosivo; si ad quinquagesimum tantum gradum Ther. Fahren. calefiat, vix partem sui ponderis vigesimam, dissolvit.

20 Aqua, Sale Ammoniaco saturata et ad prædictum gradum calefacta, Sublimati corrosivi duas tertias partes ponderis sui dissolvit: et proinde majorem habet vim solvendi hunc salem quam aqua simplex in proportionem fere, 40 : 3.

21 Si Mercurius cum Sulphure teratur, aut cum Sulphure liquato misceatur, pulverem fuscum, cito in nigrum abeuntem, constituit; qui vocatur *Æthiops mineralis*. Hic autem sublimatione fit massa rubra, friabilis, striata, quæ *Cinnabaris factitia* nuncupatur; a Cinnabari nativa, quando debita sulphuris portio adhibita fuerit, vix distinguenda.

22 Si Cinnabaris factitia, aut nativa, misceatur cum Alkali fixo, Calce viva, Limatura ferri, aliisque rebus, quibus major

major cum Sulphure competit affinitas, quam ipse habet Mercurius, et distilletur, *Mercurius* obtinebitur *purgatus*. Aliquid etiam Sulphuris quod ab Acidis præcipitari potest a cinnabari, ea cum Alkali fixo decoquenda, extrahitur.

23 Mercurius Plumbum, Stannum et Aurum facillime penetrat et friabilia reddit; et cum omnibus quidem Substantiis Metallicis (Nickel et Regulo Cobalt forsan exceptis) quanquam cum Ferro, Antimonio et Ære paullò difficilior, vel trituratione frigida aut calida, vel fusione, coit, Mixtura inde proveniens vulgò *Amalgama* rectius *Malagma* dicitur: quod est mollius, friabilior, fluidior, aut spissior pro diversa quantitate Mercurii in eo conficiendo adhibiti.

24 Amalgama Mercurii et Argenti: gravitatem habet specificam majorem gravitate specifica ipsius Mercurii.

25 Acida vegetabilia et Sales alkalinii eâdem fere methodo in Mercurium, quâ in Aurum et Argentum, agunt.



## C A P. IV.

*De Antimonio et ejus Regulo*

1 *Antimonium crudum*, est Minera a terreis et lapideis recrementis Eliquatione purgata, striis nitentibus tanquam aciculis ordinatim ferè dispositis distinctum, atque ex Sulphure et parte metallica, quæ *Regulus antimonii* appellatur, paribus plerumque quantitatibus conflatum.

2 *Antimonium crudum*, igne mitiori ustulatum, album copiosè emittit fumum; quem *Florum* nomine colligere licet. Residuum gradatim mutatur in Calcem cineream; quæ, igne fortiori fusa, vitrum facit hyacinthini aut fulvi coloris, durum, volatile, eò pellucidius quò perfectior fuerat Calcinatio et tenuior Liquefactio.

3 Vitrum antimonii, cum aqua regia digestum, colorem ei rubescentem impertit: Acidis vegetabilium aut Vinis infusum, abrasione quadam suæ substantiæ vim ipsis emeticam conciliat; quæ



quæ tamen repetitis infusionibus languescere quidem et exhauriri dicitur.

4 Vitrum Antimonii, vel Antimonium crudum, tum lapides tum metallica omnia corpora (Auro et Platina exceptis) fusione dissolvit, et volatilia reddit: et hinc a quibusdam vocatur *Lupus vorax*, *Balneum Solis*, &c.

5 Vitrum vel Calx Antimonii, cum Carbone, Sapone, aliâve substantia Phlogiston continente fusa, reducitur in Regulum; qui, si partium debita fiat refrigeratio, stellæ speciem in superficie plerumque exhibet.

6 Regulus Antimonii est Semi-metallicum durum admodum et fragile, quod a Zinco et Bismutho tum specie externâ (quâ nec cærulescit, ut Zincum, nec flavescit, ut Bismuthum) tum fusilitate difficiliori distinguitur.

7 Regulus Antimonii, in igne aperto mitiori, fatiscit in Calcem vitrescentem; at in vasis clausis, valido igne fusus, prorsus volatilis est; et Flores exhibet spiculorum splendentium instar, aqua ægrius solubiles, igne vix volatiles, et in Regulum difficillimè reducendos.

8 *Regulus Antimonii confici potest*, vel

Calcis reductione, ut in propositione 5<sup>a</sup> explicatum est; vel Præcipitatione sicca, qua nimirum interventu alterius corporis sulphur a parte regulina separatur; vel solutione humida partis metallicæ Antimonii crudi in Aqua Regia facta et Calcis inde dejiaciendæ reductione.

9 Regulus Antimonii, cum Ferro, Stanno et Zinco fusus, mixturas metallicas constituit quæ minorem habent gravitatem specificam; cum Argento, Cupro, Plumbo, et Bismutho, quæ majorem quam secundum regulas communes habere debent.

10 Reguli Antimonii cum acido nitri concocti aliquid dissolvitur, at maxima ex parte in pulverem album corroditur: si cum Acido vitriolico distilletur corroditur quoque; Acidum autem fit sulphureum, et Sulphur sæpe sublimatur. In Acido marino difficulter solvitur, facillime in Aqua Regia.

11 Si Regulus Antimonii, vel Antimonium crudum, cum sublimato mercurii corrosivo trituratione probè misceatur et distilletur, Acidum mari-  
num

num in sublimato Mercurium deferens, Regulo Antimonii sese adjunget, et cum eo elevabitur, et in Excipulum transibit, vel collo Retortæ, pinguedinis glacialis aut Butyri specie, adhærebit: unde *Butyrum Antimonii* nuncupatur. Aucto deinde igne, Mercurius vivus purissimus ascendet, et in Recipiens decurret. Denique, si Antimonium crudum adhibeatur, Cinnabaris sublimata in collo Retortæ invenietur.

12 Butyrum Antimonii aere deliquescit, et pulverem album deponit: repetitis distillationibus fit ex parte fluidum, et olei instar limpidum; ex parte, si rectè instituatur distillatio, sublimatur crystallorum forma, in aere volatiliū admodū et deliquescentium.

13 Butyrum Antimonii, aquam affundendo, lactescit; et ob Acidum debilitatum, vel propterea quod Sales perfecte medii aqua vix sunt solubiles, Regulus Antimonii in eo solutus maxima ex parte ad imum subsidet, specie pulveris albi; qui, cum aqua sæpius abluatur, insipidus fiet; et vocatur

*Pulvis Algaroth*, vel (impropriè licet, cum nihil insit Mercurii) *Mercurius vitæ*; qui, si fusus sit, vitrum succinei coloris evadet.

14 Liquor post pulveris Algaroth præcipationem remanens Butyri aliquid in se retinet soluti, quod evaporatione crystallos, distillatione salem sublimatum in collo retortæ exhibet, aere non deliquescentem, spiritu vini solubilem, sali sedativo haud absimilem. Ipse liquor, sed nullo jure, nuncupatur *Spiritus vitrioli philosophicus*.

15 Si acidum nitri a Butyro Antimonii distillatione separetur, Aqua Regia nonnullis forsan Reguli partibus inquinata obtinebitur, quæ vulgò dicitur *Spiritus Nitri bezoardicus*, a massa residua novi spiritus nitri abstractione subsequente calcinatione et ablutione conficitur pulvis; qui dicitur *Bezoardicum minerale*.

16 Sal Alkali fixum tùm coctione tùm fusione ex Antimonio crudo sulphur ejus extrahit, et sic *Hepar Sulphuris* constituit; quod partem regulinam Antimonii statim dissolvens hepar efficit Antimonii, colore hepatico vario, et aqua copiosius  
aut



aut parcius solubile, pro diversis proportionibus quibus Alkali fixum et Antimonium una admisceantur. Ex Hepate Antimonii Pharmaceutici parant medicamentum quod vocant *Crocum metallorum*, nec non *Vinum antimoniale*, *Tartarum emeticum*, &c.

17 Sulphur, quod ab Hepate Antimonii aqua soluto per Acetum aut Acidum quodcunque præcipitetur, *Sulphur Antimonii auratum* nuncupatur. Quod vero spontanea præcipitatione, dum frigescit solutio, dejicitur, *Kermes mineralis* aut *Pulvis Carthusianorum* vocatur: Utrumque a sulphure communi discrepat portione Reguli Antimonii quæ in eo continetur; a se invicem vero distinguuntur, tum proportionem partis regulinæ ad partem sulphuream, quæ minor est in pulvere Carthusianorum quàm in sulphure aurato, tum quòd Kermes mineralis alkali aliquid fixi sibi adjunctum retinet.

18 Si Antimonium crudum nitro commisceatur et deflagretur, massa residua, diversis coloribus insignis, diversis medendi viribus valet; atque *Crocus Antimonii medicinalis* aut *Crocus*



*Antimonii mitior, Antimonii Calx diaphoretica, &c.* nominatur; pro variis proportionibus quibus Nitrum et Antimonium inter se misceantur. Si ea quantitas Nitri adhibeatur quæ toti Sulphuris Antimonii deflagratione destruendo satis sit, vis maxima emetica massæ residuæ comparabitur: sin minori aut majori proportionem admisceantur, tum aut totum Sulphuris non erit absumptum, aut pars etiam Reguli Phlogisto suo privabitur. Utroque modo mitius fit medicamentum; quippe quòd vel ad Antimonii crudi, vel ad Calcis metallicæ, vires accedat.

19 Regulus Antimonii cum Sulphure liquatus in massam striatam crudo Antimonio similem frigore concrefcet.

## C A P. V.

### *De Bismutho.*

1 **B**ISMUTHUM est Semi-metallum cæteris Metallicis Substantiis (Stanno excepto) minore ignis gradu fusile; inter Semi-metalla (Nickel excepto)

excepto) fixissimum; ponderosum, fragile, ab aëre et aqua vix immutandum; Auri instar purum, non mineralifatum, semper repertum.

2 Bismuthum, in valido igne fustum, fumum exspirat inflammabilem; et, vel per se, vel cum additione, sublimari potest in Flores flavescentes: In aperto et mitiori igne, mutatur facillimè in Calcem cineream; quæ continuata flammæ reverberatione flavescit, at vix nisi dum calida restat, rubescet. Calx in Vitrum liquefit, pellucidum, fuscum, terrarum vitrificationi et usibus docimasticis apprimè accommodatum.

3 Acidum Nitri Bismuthum dissolvit magnâ cum Effervescentia et vaporum eructatione. Solutio, evaporata, præbet cryсталlos albas: affusione aquæ puræ, Bismuthum partim in ea suspenditur; partim ab ea dejicitur; et pulvis sic dejectus vocatur *Magisterium Bismuthi, Blanc d'Espagne, vel Blanc des perles.*

4 Acidum Salis marini, cum Bismutho coctum, parum ejusdem dissolvit: Acidum Vitrioli nihil, quod præcipitari potest; at colorem rubescentem ab eo extrahit.

5 Si Acidum Vitrioli in Bismuthum fufum infundatur, vel ab eo abstrahatur, sulphuris aliquid colore fusco sublimatur, et odor arsenici, sentitur.

6 Acida Vegetabilia aliquid Bismuthi, quod ab Alkali præcipitari potest, coctione dissolvunt. Alkalia fixa Phlogisto imbuta, et alkalia volatilia, in Bismuthum eodem fere modo, quo in Argentum, agunt.

7 Bismuthum, cum Sulphure fufum, cum eo coit et massam efformat striatam, Antimonio crudo quodammodo similem, et facile liquefcentem.

8 Bismuthum cum omnibus Metallicis Substantiis (Zinco et Nickel exceptis) sese fusione commiscet et fluxilia reddat: Stannum dealbat, durius, magis sonorum, et fragilius simul efficiens.

9 Mercurius et Bismuthum, paribus ponderibus unâ fusa, Amalgama solidum constituunt. Idem dici potest de Mercurio et Plumbo. At Mercurius, Plumbum, et Bismuthum, paribus ponderibus, Amalgama efformant fluidum: ab hoc Bismuthum, sub specie pulveris grysei, brevi separatur; at Plumbum  
adeo

adeò tenuiter solutum restat, ut per Corium unà cum Mercurio transeat.

10 Aqua ebullit gradu caloris, in Thermometro Fahrenheitiano, 212°. Bismuthum liquefcit gradu 460°. Stannum liquefcit gradu 410°. At Mixtura, ex paribus quantitibus stanni et bismuthi conflata, liquefcit gradu 280°.

11 Si Plumbum, Stannum, et Bismuthum unà fundantur paribus ponderibus, Massa mixta minori dicitur liquefcere ignis gradu quàm eo quo aqua ebullit.

## C A P. VI.

### *De Zinco et Lapide calaminari.*

1 *LAPIS Calaminaris* tertiam vel majorem ponderis sui partem, Florum specie nec sulphur nec arsenicum redolentium, ustulatione amittit. Si cum pulvere carbonum permisceatur, et igne vehementissimo vasis quantum fieri poterit clausis distilletur, Substantiam præbebit Metallicam, ex cæruleo albam; quæ *Zincum* appellatur.

2 *Zincum*



2 *Zincum* est Semi-metallum: vel striatum, ut *Zincum Gossariense*; vel tessellis distinctum, ut *Indicum* et *Anglicanum*; durum; sonorum, malleo (dum frigidum est) aliquantum cedens; in pulverem trituratione non reducendum; in igne liquefcens simul ac rubet, at *Plumbo* difficilior; sæpius fufum, fit (*Stanni* instar) durior, fragilior, minus fusile, et calcinationi minus obnoxium: ab aëre et aqua non multum mutatur.

3 *Zincum*, igne leniori fufum, mutatur in *Calcem*: at si violentior sit ignis, inflammatur cum strepitu, et odorem emittit arsenicalem; flamma lucidissima, viridis, ne minima fuligine inquinata, durat donec tota *Zinci* massa sit combusta et in Flores albos, levissimos, *Gossypio* similes, (quos *Lanam* nuncupant *Philosophicam*) sublimata.

4 *Zinci* Flores ab *Acidis* omnibus dissolvuntur; *Phlogisti* additione, in vasis clausis *reducuntur*; in igne fixi restant, et in vitrum coloris prafini tandem convertuntur.

5 *Acida* omnia mineralia, nec non *Acetum* faciliiori negotio *Zincum* quam cætera



cætera Metallica Corpora dissolvunt:  
Si cum Oleo vitrioli distilletur Sulphur  
sublimatur, Residuum Arsenicum olet.

6 Zincum dum, ab Acido vitriolico  
aquofo, vel ab Acido marino concen-  
trato, dissolvitur, Aerem, vel vaporem  
elasticum, foetidum, inflammabilem  
copiose emittit; at nihil Sulphuris  
præbet.

7 Pondus totum Aeris inflammabilis,  
qui per solutionem Zinci in Acido vi-  
triolico generatur, æquale circiter de-  
prehenditur parti vicesimæ-quartæ pon-  
deris ipsius Zinci.

8 Densitas aeris inflammabilis fere  
eadem est ex qualicunque metallo, vel  
qualicunque Acido sit genitus.

9 Aer inflammabilis, per Solutionem  
Zinci generatus, levior est aere com-  
muni (Thermometro denotante gradum  
50 et Barometro 30 uncias) in propor-  
tione circiter 11 : 1.

10 Zincum in Acido vitriolico so-  
lutum, evaporatione concrefcit in Cry-  
stallos, quæ vocantur *Vitriolum Album*  
vel *Goslariense*.

11 Zincum cum omnibus Metallicis  
Substantiis (Bismutho excepto) fusione

uniri potest. Paullò difficilior coit cum Ferro; facilius cum Cupro; cum reliquis facillime.

12 Zincum ab omnibus Metallicis Corporibus distinguitur; et ab iis depurari potest: eò quòd cum Sulphure aut Hepate Sulphuris colliquefactum, nullam ab iis mutationem patitur.

## C A P. VII.

### *De Cobalto et ejus Regulo.*

I **S**I Cobaltum ustulatione in furno reverberii ab arsencio liberetur, in pulverem postea redigatur, et cum duplo vel triplo arenæ aut silicum calcinatorum et contusorum misceatur, mixtura aquâ irrorata in massam quasi lapideam brevi indurefcit, et *Zafferæ* vocatur.

2 Omnia Acida mineralia *Zafferæ* venalis aliquid dissolvunt; acida vitrioli et nitri colorem fulvum aut roseum ab ea extrahunt qui calore non mutatur; cum ab acido marino facta est solutio color ejus, dùm frigida manet, est fulvus  
aut

aut intense viridis prout acidum est aquâ dilutum necne; at dum calefcit solutio fulvus mutatur in viridem.

3 Zaffera in acido vitriolico soluta, forma pulveris cærulei præcipitatur ab alkali fixo phlogisto imbuto; si uberior alkali copia adhibeatur præcipitatum fit e cæruleo gryseum quod tamen affusione spiritus salis colorem cæruleum recuperat prorsus, uti evenire solet cum cæruleum Berolinense a solutione vitrioli viridis dejicitur.

4 Zaffera in acido vitriolico soluta gallarum decocto affundendo nigrescit.

5 Zaffera ab acido quovis præcipitata, cum oleo aut sevo mista et igne leniter calcinata fit pulvis niger qui magneti obsequitur.

6 Zaffera igne liquefcit in vitrum cæruleum, quod cum in pollinem subtilissimum reducitur vocatur *Smaltum* vel *Encaustum cæruleum*.

7 Si Zaffera aut smaltum cum substantia inflammabili una fundantur, odor arsenicalis sentitur, et substantia metallica in fundum præcipitatur quæ dicitur *Regulus Cobalti*.

8 Regulus Cobalti a reductione Zafferæ

feræ ab acidis præcipitatæ vel smalti  
proveniens est fragilis admodum et  
durus, coloris grysei, texturæ lævis at  
non granulata; a magnete promptis-  
sime atrahitur, calcinatione mutatur in  
pulverem nigrum qui ab igne vehe-  
mentiori in vitrum cæruleum, ferri in-  
star, liquefcit.

9 In Regulum Cobalti, acida vitrioli  
et falis marini vix agunt; solutio in  
acido nitri facta est rubra, in aqua regia  
viridis.

10 Regulus Cobalti per Alkali fixum  
commune ab aqua regia præcipitatur  
in pulverem rubescentem, per Alkali  
phlogisto imbutum in pulverem cæru-  
leum.

## C A P. VIII.

### *De Nickel.*

1 **N**ICKEL est Semi-metallum  
ex gryseo rubens, cæteris minus  
fusile, in calcem viridem mutabile, quæ  
in igne etiam fortissimo vix liquefcet in  
vitrum.

2 Si Nickel et Bismuthum una fundantur et sub fusione admisceantur, Nickel conjunctionem cum Bismutho, prorsus aufugiens semper supernatat, et Bismuthum in imum subsidet.

3 Acidum vitriolicum sive concentratum, fit sive aqua dilutum Nickel non dissolvit: Acidum marinum paullo segnius in illud agit; Acidum nitri cum fumorum rubrorum eructatione violenter dissolvit, solutio viret, et ab Alkali volatilis affusione fit cærulea.

4 Dum Nickel ab acido nitri dissolvitur, flocculi grysei ab eo separantur, qui in igne et sulphuris et arsenici dant indicia.

5 Nickel ab acido nitri per alkali fixum præcipitatur in pulverem subviridem.

## C A P. IX.

### *De Plumbo sive Saturno.*

1 **P**Lumbum est Metallum imperfectum, minus quam cætera durum, elasticum, tenax, et sonorum;



Stanno minus fusile: ab actione aeris et aquæ rubiginem quandam gryseam contrahit, at difficiliùs corroditur quam Ferrum.

2 Filum Plumbi cylindricum cujus diameter decimæ parti unciaæ æqualis est sustinere potest pondus  $29\frac{1}{4}$  Librarum.

3 Plumbum in igne fluit antequam candescit; aucto calore effumat et ebullit; fusum in superficie tegitur pelliculâ cinereâ versicolore; quâ semotâ vel cum plumbo mixtâ, altera enascitur; et sic tandem tota massa in Calcem converti potest quæ vocatur *Plumbum ustum*. Hoc autem, Plumbo in hunc finem adhibito, levius est.

4 Plumbum ustum, si subitam ignis violenti actionem patiatur, fit Olei instar fluidum, et in Scoriam convertitur vitrescentem, ex squamosis lamellis, flavescentibus aut rubescentibus, pro diverso ignis gradu, constantem et *Lithargyrus* vocatur. Lithargyrus æquè ac Plumbum ustum in igne mitiori diutiùs detentus, flammâ simul in superficiem ejus supernè reverberatâ, fit primo flavus, deinde aureus et Gallico idiomate

idiomate a Pictoribus dicitur *Massicot*; tandem ruber, et vocatur *Minium*.

5 *Massicot* in igne calefactus fit e flavo ruber, frigescens iterum fit flavus.

6 Plumbum in Minium conversum, licet multum de substantiâ suâ Florum formâ deperdat, pondere plusquam decimâ parte augetur; at Minium illud nihilominus, *Reductione factâ*, pondus æquale ponderi Plumbi ex quo erat confectum minimè præbebit.

7 *Lithargyrus*, *Massicot*, Minium aliæve Plumbi Calces faciliè liquefcunt in Vitrum coloris aurei.

8 *Lithargyrus* vel Vitrum Plumbi cum lapidibus, vel terris quibuscunque refractariis fusus, mirificè earum liquefactionem promovet; et Metallica corpora (Auro, Platinâ et Argento exceptis) in Scoriam vel Vitrum secum rapit: et hinc commodè adhibetur tùm ad Vitra conficienda pellucidissima, tùm ad Metalla perfecta a Mineris et Metallicis imperfectis purganda.

9 Plumbum ab Acido Nitri aquâ diluto copiosè dissolvitur. Solutio evaporata in Cryсталlos concrefcit, albas, pyramidales, sapore dulces, austeras;

quæ in vase clauso igni expositæ crepitant at non inflammantur.

10 Plumbum in Acido Nitri solutum, inde præcipitatur ab Acidis tum Vitrioli tum Salis marini quibus sese conjunct: cum Acido marino sic conjunctum Plumbum quod corneum vocant, cum Acido Vitrioli, Vitriolum Plumbi constituit.

11 Si Plumbum sit cum Acido Vitriolico concoctum aliquanta ex parte dissolvitur; Distillatione in vasis clausis institutâ, totum corroditur in massam albam aquâ ex parte solubilem; vapor Sulphureus, qui inflammationem nonnunquam admittit, sub fine exit, et Sulphur simul sublimatur.

12 Si in Plumbum fusum Acidum Vitriolicum infundatur, Sulphur communi prorsus simile statim sublimatur.

13 Si Plumbum sit cum Acido marino coctum, exigua ejus pars ab Acido dissolvitur. Solutio, debitâ factâ evaporatione, Cryсталlos sistit, albas, pelucidas, Nitro haud absimiles; vel cum adhuc calida sit in aquam frigidam infusa, præcipitatum præbet eximie album.

14 Acetum

14 Acetum longâ digestionem parum Plumbi dissolvit; at in vapores resolutum illud rodit in rubiginem squamosam, friabilem, insipidam, inodoram, quæ vocatur *Cerusa alba*.

15 Cerusa alba, vel Lithargyrus vel Minium si cum Aceto coquatur ab eo dissolvitur. Quælibet harum solutionum usque ad Mellis fere crassitiem evaporata, Salem præbet crystallinum, dulcem, stipticum, venenosum, dictum *Saccharum Saturni*. Quod distillatione spiritum ardentem præbet.

16 Olea Vegetabilium sive Stillatitia sive pressa Plumbum integrum vel Calces ejus quælibet, (copiosius autem Minium) in coctione dissolvunt. Solutiones ab Aceto possunt decomponi: et Olea pressa sic a Plumbo liberata Spiritu Vini fiunt solubilia.

17 Alkalia fixa per Calcem vivam acuata, parum Plumbi dissolvunt, multum redunt.

18 Si Calx quælibet Plumbi vel Plumbum integrum cum Sulphure liquefiat, in Mineram, igne vix fusibilem at naturali Plumbi Mineræ specie per-similem mutabitur. Plumbum cum



Arsenico fufum in Flores partim fublimatur, partim in Vitrum hyacinthinum mutatur.

19 Plumbum, cum omnibus fubftantiis Metallicis (Ferro excepto), per fufionem commifceri poteft.

20 Si Mixtura Metallica ex Plumbo et Stanno confefta fit fufa cum ferro, Stannum (connubium Plumbi refpuens) fefe Ferro adjunget.

21 Si Mixtura Metallica ex Ferro et Cupro vel ex Ferro et Argento conflata, fit fufa cum Plumbo, Cuprum vel Argentum Ferrum deferet, et cum Plumbo in mafsam coibit.

22 Si Mixtura Metallica ex Plumbo et Stanno confefta fit fufa cum mixturâ ex Ferro et Argento conflatâ Stannum (Plumbum deferens) fefe Ferro adjunget; et Plumbum fimul Argenti connubium petit, et mafsas (utcunque fub fufione agitantur) diftinctas, cum frigefcunt, femper exhibebunt.

23 Plumbum fcriptorium five Mobilidæna, igne violentiffimo occlufo, ferè nihil; igne aperto decimam quartam partem ponderis amittit. Refiduum



duum ne particulam præbet Plumbi at Ferri Magneti obedientis multum.

24 Plumbum scriptorium, in pol-  
linem comminutum, cum Sulphure li-  
quato intime coit et massam vix a verâ  
Minerâ distinguendam constituit; nisi  
quòd in flammâ candelæ accenditur et  
fumum Sulphureum exspirat.

## C A P. X.

### *De Cupro sive Venere.*

**C**UPRUM est Metallum im-  
perfectum; Auro, Argento,  
Plumbo et Stanno magis durum et  
elasticum, at in igne minus fusile;  
Plumbo et Stanno magis ductile et  
fixum: et omnium maximè sonorum.

2 Cuprum, diu candescens, tandem  
fluit; fusum, fit humidi admodum im-  
patiens; in aperto igne violentiori si  
detineatur, Pondus ejus diminuitur,  
Superficies comburitur et in Crocum  
subrubrum convertitur, qui ab igne  
solari densato vitrum fit rubrum.

3 Ea est *Cupri tenacitas* ut filum  
z 4 cylin-

cylindricum, cujus diameter æqualis est decimæ parti unciaë, sustineat pondo 299 $\frac{1}{4}$ .

4 Cuprum ab omnibus Acidis, tùm mineralibus tùm vegetabilibus, dissolvitur, nec non ab Alkali fixo et volatili, a Salibus mediis, Oleis expressis et essentialibus; ab ipsis Aere et Aquâ eroditur et in Æruginem mutatur: *frictu calefactum, odorem; manducatum, saporem nauseam moventem præbet.*

5 Cuprum ab Acido Nitri facillimè dissolvitur; ab Acido marino difficiliùs, ab Acido vitriolico difficillimè, nisi acidum sit concentratum et ebulliens. Hæc Solutio crystallos dat, cæruleas, figura rhomboidales, in aere non deliquescentes, quæque *Vitriolum* constituunt quod a Mercatoribus *Romanum* aut *Cyprium*, vel *Cupercosum cæruleum* vocatur.

6 Ab aquis cæmentatoriis ut vocantur, vel, quod eodem redit, a vitriolo cæruleo in aquâ soluto Cuprum purissimum præcipitatur additione ferri. Solutio virescit, acido ferrum subeunte.

7 Si Cupri lamellæ sint alternatim stratae cum vinaceis exsiccatis (quæ  
cum

cum vino generoso per fermentationem in acetum abeunte aliquot dies priùs fuerint digestæ) erodentur, et superficies singularum viridi-cærulea quadam cooperietur efflorescentia, quæ *Ærugo* vel *Viride Æris* nuncupatur.

8. Cuprum vel Viride Æris venale (quod constat ex Cupro et Acido in proportionem circiter 5 : 7.) ab aceto stillatio solutum, dat per inspissationem crystallos virides, aëre sicco in pulverem fatiscentes, quæ apud Mercatores improprie dicuntur *Viride Æris distillatum*.

9. Viride Æris distillatum, dimidium penè sui ponderis, Acidum admodum concentrati distillatione præbet, quod *Acetum radicatum* vel *Spiritus Veneris* vocatur.

10. Spiritus Veneris est aliquantùm volatilis, odorem exhalat suffocantem; igne Spiritus quemadmodum Vini, est inflammabilis; crystallisationem admittit; et *Ætherem acetosum* distillatione cum Spiritu Vini exhibet.

11. Residuum ex Spiritu Veneris præparatione in Cuprum reducitur per simplicem cum Borace fusionem.

12. Si Cupri limatura et Sublimatum Mercurii

Mercurii corrosivum unâ distillantur, Acidum marinum Cuprum invadens, illud in massam resinæ citrinæ vel rubræ similem mutabit.

13 Cuprum ab Oleis vel Spiritu Vini solutum, vel in integro etiam suo statu igne utcunque combustum, colorem viridem flammæ impertit.

14 Cuprum calcinatum, præcipitatum, sulphuratum, qualicunque demum modo paratum, vel etiam integrum vitro mistum et sine additione fusum, colore viridi vitrum imbuat.

15 Si Cuprum sit cum Lapide Calaminari aliâve Zinci Minerâ, debitâ adhibitâ encheiresi colliquefactum, pondere, ad tertiam vel majorem ponderis totius partem, augebitur. Mixtura Metallica flava conflabitur, quæ *Aurichalcum* vocatur.

16 Aurichalcum frigescens Cupri malleabilitatem habet; igne calefactum fit fragile; sed levius, durius, fusilius, magis sonorum, scorificationi in igne mitiori, actioni aëris et aquæ ipso Cupro minus obnoxium deprehenditur.

17 Aurichalcum in igne diutius fustum mutatur in Cuprum; quippe Zincum  
cum



cum five pars metallica Lapidis Calaminaris comburendo dissipatur.

18 Aurichalcum, cum Mercurio trituratione amalgamatum, mutatur in Zincum: quippe Cuprum, restante Zinco, Mercurio adjungitur.

19 Cuprum, cum Zinco liquatum in proportione 4 : 1. vel secundum alias proportionem, Mixturas varias Metallicas constituit, colore Auro perquam similes, at propter Zinci impuritatem plerumque fragiles; quæ vocantur *Métalla Principis Ruperti*, *Métalla aurea sophistica*, *Métalla Tombacina*, &c.

20 Cuprum album conficitur ex Cupro colliquefacto cum Arsenico per Nitrum fixo. Sæpius fustum pondere diminuitur parte circiter septimâ, in Cuprum rubrum mutatur et sub fusione odorem efflat arsenicalem.

21 Si Cuprum et Stannum, quibus pauxillum Aurichalchi aut Bismuthi nonnunquam adjicitur, per fusionem commisceantur, Mixturam Metallicam constituent subflavam, duram, sonoram, fragilem, Aeris et Aquæ actioni ipso Cupro longe difficiliter cedentem; quæ vocatur *Metallum tormentorum bellicorum*,



*rum, Campanarum, Æs Caldarium, Bronze, &c.* pro varia proportionē quibus Cuprum et Stannum unā liquantur.

22 Si æquales magnitudines Cupri et Stanni unā fundantur, Mixtura ex his conflata minor erit, parte plusquam quarta, quam cuprum et stannum simul sumpta; pondus tamen haud mutabitur, et gravitas specifica fiet ipsâ Cupri gravitate specificâ major.

## C A P. XI.

### *De Ferro sive Marte.*

1 **FERRUM** est Metallum imperfectissimum; aëri et aquæ expositum, omnium facillime rubigine exeditur; cæteris, (Platinâ exceptâ) minùs fusile, et (excepto Cupro) magis sonorum; duritiæ et elasticitate omnia exsuperat; et unicum est quod a Magnete atrahitur.

2 Ferri Filum cylindricum, cujus Diameter decimæ parti uncia equalis est, sustinere potest pondus 450 Librarum. Hinc Ferrum videtur omnium Metal-

Metallorum esse tenacissimum. Nam tenacitas non videtur esse mensuranda ponderibus quibus disrumpantur fila metallica earumdem Diametrorum, ut affolet, sed quibus cohæsiō datarum Quantitatum materiæ superatur; vel ponderibus, quibus fila, cujus Diametri sunt in reciprocâ subduplicatâ ratione gravitatum specificarum, disrumpuntur.

3 Ferrum, violentiori motu attritum, candescit; igni fortiori expositum, in superficie quodammodo vitrescit; ad fusionem accedens scintillat, fumum vel flammam quasi Sulphuream emittit, et in calcem mutatur: at in clauso vase Calcinationem non patitur.

4 Si Ferrum excandescens follium continuo flatu urgeatur, Calor ejus augebitur et liquefcet.

5 Ferrum ab Acido vitriolico aquoso facillimè dissolvitur. Solutio hæc evaporata Salem præbet, viridem, rhomboidalem, qui vocatur *Sal Martis, vitriolum* vel *Cuperosum viride*.

6 Ferrum durissimum, sub aqua vitriolica per plures Annos submersum, fit, ut dicitur, mollitie et Colore Mollibdenæ persimile.

7 Acidum

7 Acidum nitrosum agit violentè in Ferrum; marinum paullò segniùs; utrumque cum eo Salem deliquescentem efficit; qui, cùm Acidum marinum adhibetur, in Spiritu Vini est maximâ ex parte solubilis.

8 Acida omnia Vegetabilia, tùm nativa tùm fermentatione generata, nec non Sal Ammoniacus, Sales Alkalini, Aqua, et Aer, agunt in Ferrum et varia inde Pharmaceuticis suppeditantur medicamenta. Horum præcipua sunt 1° *Croci martiales* vel *Calces Ferri*, colore rubro aut flavescente tinctæ, sive parantur Calcinatione, Præcipitatione, vel simplici Actione Aquæ, vel Aquæ et Aeris conjuncta. 2° *Tincturæ martiales*, vel Ferrum variis modis in Spiritu Vini solutum. 3° *Flores martiales*, vel Ferrum cum Sale Ammoniaco sublimatum. 4° *Lixivium Martis*, vel Residuum a Sublimatione Ferri cum Sale Ammoniaco quod in liquorem deliquio redactum est. 5° *Vinum Chalybeatum*, vel Ferrum in vino Rhenano digestionem solutum. 6° *Rotuli martiales*, et *Tartarus Chalybeatus*, vel Ferrum cum Tartaro conjunctum, &c.

9 Limatura

9 Limatura ferri aquâ madefacta sæpius et exsiccata, in Rubiginem tota convertitur, pondere augetur, et *Salem volatilem*, ut dicitur, distillatione exhibet.

10 Cum Ferrum in Acido vitriolico vel marino dissolvitur, vapor elasticus, foetens, sulphureus generatur; qui ad motionem Candelæ inflammatur.

11 Si partes æquales Scobis ferreæ et Sulphuris vulgaris in mortario triturentur, et in pastam aqua formentur, Mixtura, paucis elapsis horis, incalescit, turgescit, vaporem sulphureum expirat, et si quantitas sit satis magna, flammam sponte concipit.

12 Ferrum candens cum Sulphure facillimè coit, et ab eo reducitur in Speciem Mineræ aere efflorescentis, Pyritæ martiali efflorescenti persimilis.

13 Ferrum, uberiori Phlogisto imbutum, mutatur in *Chalybem*.

14 Chalybs, Phlogisto superabundanti privatus, mutatur in ferrum. Quær. Utrum Phlogiston sit unicum Principium, ex cuius majore vel minore copiâ pendet inter Ferrum et Chalybem discrimen?

15 Chalybs,



15 Chalybs, igne calefactus et aqua frigida subito immersus, fit durus admodum et fragilis; et sic a ferro distinguitur, æquè ac majori suâ gravitate specificâ, fusilitate in igne faciliore, elasticitate majori, Colore magis nigricante, et textura magis compacta, quæ ex granis exiguis, diversarum in diversis Generibus magnitudinum constat.

16 Chalybs expolitus, per diversam ignis actionem, diversos exhibet Colores. Primò flavescit, deinde flavet, rubescit, purpurascit, livescit, nigrescit, tandem aucto adhuc igne candescit.

17 Chalybs, igne candefactus, et immersione in aquam induratus, duritiem suam gradatim amittit dum colores diversos prædictos suscipit; et ex hac coloris mutatione de duritie instrumentorum quæ singulis operibus conveniat judicium ferunt opifices.

18 Ferrum in Acidis solutum adfusionem decocti Gallarum (si solutio saturetur) nigrescit, et lente in fundum subsidet, specie nigri pulveris; qui ab acido maximâ ex parte iterum dissolvi potest.

19 Ferrum in Acido vitriolico solutum,



tum, inde præcipitari potest Alkali fixo quod phlogisto qualicumque saturetur idque sub formâ pulveris cærulei; qui a pictoribus nuncupatur *Cæruleum Bærolinense*.

20 In Cæruleum Bærolinense Acida non agunt: Alkalia fixa materiam colorantem ab eo extrahunt, et eâ saturari possint.

21 Alkalia fixa, cum Materia colorante Cærulei Bærolinensis saturata, cum Acidis non effervescent; colorem Cæruleum Vegetabilium non viridescent; et Ferrum, in Acido quocunque solutum, sub cæruleo colore præcipitant.

22 In omni ferè Arenâ, in Argillis coloratis, in Lapide Lazuli, in plerisque lapidibus pretiosis, in cunctorum ferè Vegetabilium cineribus, in Crassamento sanguinis, in Urinâ, et in carne Animalium, in cineres redactis, vel etiam leni calore exsiccatis, particulæ plurimæ reperiuntur quæ a Magnete attrahuntur.

23 In Ossibus Animalium, in pinguedine, et parte sanguinis ferosâ, calcinatis, vel nullæ vel perpaucæ depre-

henduntur particulæ Magneti obsequentes.

24 Particulæ quæ Magnetis Vim patiuntur plures reperiuntur in sanguine Hominum et Quadrupedum, quam in Sanguine Piscium; et plures in Sanguine Piscium quam Volatilium: et, in genere, quò uberior sit Globulorum rubrorum in sanguine innatantium copia, eò major deprehenditur quantitas particularum, Magnetis actioni obedientium.

25 Particulæ, a cineribus magnete separatae, Acidis dissolvi nequeunt.

26 Ferrum, cum Plumbo fusum, omne cum eo respuit consortium, et ei perpetuo supernatat: at aliis Metallicis Substantiis (zinco forsan, quod calorem debitum sustinere nequeat, excepto) facile per fusionem coit, et Mixturas varias Metallicas constituit: Hæ autem, si ejus cum Regulo Antimonii (ob Sulphur forsan, quo Regulus inquinatur) mixturam excipias, Magnetis attractionem patiuntur.

27 Ferrum cum Mercurio vix amalgamari potest, at sub eo nihilominus per aliquot Dies submersum, vel vapor

pori Mercuriali expositum fit, ut dicitur, fragile et friabile.

28 Ferrum materia vitrescente per fusionem mixtum, minore ignis gradu viridem, majore cæruleum ei semper impertit colorem.

## C A P. XII.

### *De Stanno sive Jove.*

**S**TANNUM est metallum imperfectum, præ cæteris metallis levius et in igne fusilius; at, Plumbo excepto, minima duritie, tenacitate, elasticitate, sono gaudens: Stridor quidam inter plicandum, ei, Zincum si excipias, est proprius; aëris et aquæ actioni parum profecto cedit.

2 Stanni filum cylindricum, cujus diameter decimæ parti uncix æqualis est, sustinere potest pondus 49 Librarum.

3 Stannum usque fere ad fusionem calefactum, vel post fusionem frigescentis et in solidum tantum non condensatum, fit rigidum admodum et fragile, et si motu velociori in eo

statu conquassetur in granula minuta, porosa erit divulsum. Plumbum et Aurichalcum similem subeant comminutionem, at Aurum et Argentum quæ fusioni proxima fiunt tenaciora, Granulationem ea methodo non admittunt.

4 Stannum fufum odorem exspirat arsenicalem, scintillas emittit, et in calcem albescentem, difficilime reducendam, et in foco etiam speculi ustorii vix vitrificandam, citò calcinatur.

5 Stannum in igne fortissimo diutius detentum dicitur partim in flores sublimari, partim in calcem rubescentem redigi, partim in vitrum pellucidum coloris rubei mutari.

6 Stannum et Plumbum una fusa turgescent, et lucida quasi combustionem citius in cineres exuruntur, quam singula seorsim calcinata.

7 Si Calces stanni et plumbi cum filice calcinato vel vitro pellucidissimo contuso et sale alkalino fixo simul fundantur, massam vitrescentem lacteam in arte fictili et encaustica utilissimam constituent; cui si calces aliorum metallorum



tallorum conjungantur, encausta varia diversimode colorata conficientur.

8 Si stannum cum Acido vitriolico concentrato usque ad siccitatem in vasis clausis distilletur, multum exhibit vaporis sulphurei qui inflammationem nonnunquam admittit, et sulphur simul in collo retortæ sublimatum invenietur. Quod si acidum sit aqua dilutum, vapor est semper fere inflammabilis, et sulphur præcedente, ut videtur, minus flavum et in minori copia generatur.

9 Stannum in acido vitriolico aquoso copiose dissolvitur; solutio, debitâ factâ evaporatione, crystallos præbet albas, tenues lanugini similes, quas *Vitriolum Jovis* nominare liceat.

10 Stannum ab acido marino calefacto et concentrato promptius dissolvitur, et vapor inde inflammabilis sulphur et Arsenicum redolens producit, cujus pondus æquale circiter deprehenditur parti quadragesimæ quartæ ponderis Stanni soluti.

11 Si Stannum cum Sublimato mercurii corrosivo distilletur, primo in excipulum cadent guttulæ quædam acidi marini, deinde prodibit liquor eximie



fumans, qui *Liquor fumans Libavii* dicitur (in æthere marino conficiendo utilissimus), tandem in collum retortæ stannum cum acido marino conjunctum sub forma solida elevabitur.

12 Stannum ab acido nitri promptissime dissolvitur, vel potius ni cautè instituatur solutio in calcem corroditur: Ab aqua regia solutio ejus facillime absolvitur; hæc solutio est coloris et spissitudinis variæ, haud raro in solidum, juris instar gelati, concrescit.

13 Stannum in aqua regia solutum, sub leni evaporatione arsenici plerumque crystallos exhibet: quod ab imperfecta mineræ calcinatione provenire censendum est, cum datur stannum ab omni arsenico immune.

14 Stannum in acido nitri vel in aqua regia solutum, et cum purpurascenscentibus decoctionibus Ligni Brasiliæ, Cochinellæ, &c. mixtum, colores earum in usus tinctiles eximie exaltat.

15 Si Stannum, argentum vivum, sulphur, et sal ammoniacus accuratè admisceantur, ac in igne forti sublimentur, superiora vasorum petet quædam

dam Cinnabaris, in imo remanebit massa levis, friabilis, coloris aurei, quæ vocatur *Aurum Musivum* vel *Musivum*, quod phlogisti additione in stannum reducatur.

16 Stannum in Aceto, vino Rhénano, et succis nativis acidis vegetabilium dissolvi potest.

17 Stannum cum omnibus metallicis corporibus facillime fusione commisceri potest; fragilia (ob arsenicum forsan quo inquinatur) reddit, et difficillime ab iis separatur.

18 Stannum cum plumbo colliquatum fit rigidius; fusum cum Bismutho, Zinco, Regulo Antimonii, &c. fit magis durum, album, et sonorum.

19 Stannum foliatum cum mercurio facillime in Amalgama coit, quo superficies posteriores speculorum planorum obduci solent.

20 Si Stannum, Plumbum, et Bismuthum una fundantur, et cum Mercurio commisceantur, Amalgama constituent ad superficies concavas obtegendas apprime idoneum.

21 Stannum fusum cupri et ferri non tantum superficiei adhærescit, sed

in intimiora penetrat, ut videre licet in ferreis instrumentis quibus opifices utuntur ad laminas ferreas stanno illinendas.

### C A P. XIII.

#### *De Argento sive Lunâ.*

1 *Argentum* est Metallum perfectum; ductilitate et fixitate Auro proximum; fluit cum primùm candescit, et paullo facilius quam Ferrum, Cuprum et Aurum: Aurum, Plumbum et Stannum duritie et elasticitate superat; omnibus Metallis (Cupro excepto) magis sonorum est; actione aëris et aquæ prorsus immutabile, at a Sulphureorum halitu infuscatur.

2 *Argentum*, ut ait Kunckelius, igni vehementissimo furni vitriarii per mensem expositum, 64<sup>a</sup> circiter ponderis parte diminutum deprehendebatur; spatium duorum mensium, ut ait Gastus Clavius, decrementum ponderis in eodem igne patiebatur æquale parti duodecimæ ponderis totius; ut ait Hombergius, vitro ustorio expositum in fu-

num abiit, sed in Vitrum non fuit conversum.—Annon ponderum decremента ignobili alicui Metallo quod cum argento misceatur, potius quam defectui fixitatis in Argento ipso, attribui debeant?—Annon fumus, quem observavit Hombergius, ipsi Argento in Auras acto, potius quam Argento in partes dissimiles resolutio, referendus est?

3 Ea est *Argenti tenacitas*, ut filum Cylindricum, cujus diameter æqualis est decimæ parti unciae, sustinere possit pondus 270 Librarum.

4 Argentum non solvitur in Acido Salis marini, viâ humidâ; nec in Aquâ regiâ; difficillimè quidem in Oleo Vitrioli, etiam ebulliente; promptissime verò in Acido Nitri solvitur. Solutio in Acido Nitri facta, si depuratum sit Argentum, est pellucida, excolor, amara, caustica.

5 Solutio Argenti, in Acido Nitri facta, Capillos, Cutem, Ossâ, cæteraque Animalium solida, nec non Achatem, Jaspidem, pluresque alios lapides fusco vel nigro colore tingit: evaporatione in Cryсталlos concrescit albas, quæ in igne fusæ colorem induunt nigrum,



grum, et massam causticam constituunt quæ vulgò dicitur, *Luna caustica* vel *Lapis infernalis*; quæ vi minori, aut majori, causticâ pollet, prout Solutio est penitus, vel ex parte, saturata.

6 Argentum, ex solutione suâ in Acido Nitri præcipitatum, fit solubile, per Acidum vegetabile, vel nativum, vel ex fermentatione generatum: per Alkali volatile et Alkali fixum, quod conficitur calcinando Sale alkalino fixo, cum sanguine bovino: sed nec per Alkali fixum commune, vel causticum, vel Calcinatione cum Carbone vegetabili paratum, nec per Nitrum fixum detonatione cum carbone vegetabili aut animali. Hoc autem delectui salis alkalini volatilis quo alkali fixum sanguine bovino calcinatum imbuitur, attribui forsân potest.

7 Si in Solutionem Argenti Acido Nitri factam, infundatur Acidum vitrioli, vel Salis marini, vel Solutio cujuscunque Salis, hoc vel illud Acidum continentis, Argentum deferat Acidum Nitri, et cum Acido vitrioli vel Salis marini conjunctum, Coaguli instar albi, in fundum subsidet.



8 Argentum, cum Acido marino conjunctum et igne fustum, fit Corpus admodum volatile; ex parte pellucidum et quasi corneum; et exindè *Luna cornea* appellatur: quæ in aquâ vix solvitur, et quinta circiter parte, accretione Acidi, Argento soluto ponderosior est.

9 Si Argentum sit cum Acido vitriolico usque ad siccitatem distillatum, vapor prodit sulphureus, at nihil sulphuris sublimari observatur; ipsum Argentum in massam duram flavescentem, aquâ maximâ ex parte solubilem, et CrySTALLISATIONIS capacem convertitur.

10 Si in Argentum fustum Acidum vitriolicum infundatur, vapor prodit eximie sulphureus; at Sulphur non separatur.

11 Argentum ab omnibus Metallicis Substantiis (Auro et Platinâ, et per parvâ forsan Cupri quantitate exceptis) Cupellatione liberatur. In Acido Nitri solutum, et inde ab Acido marino præcipitatum, fit, reductione factâ, ab omni Corpore heterogeneo immune et purissimum habetur.

12 Argentum,

12 Argentum, cum Sulphure fufum, in Maſſam fragilem convertitur, colore et mollitie plumbi ſimilem. Hâc fuſione minima pars Auri a Maſſâ quâlibet Argenti ſeparari poteſt.

13 Argentum, cum Cupro Colliquefactione conjunctum, fit magis durum et ſonorum. Quod ſi cum Stanno vel Regulo Antimonii conjungatur, pene omnem ſuam Malleabilitatem perdit.

14 Argentum purum ponitur æquale duodecim denariis. Si ejus pars duodecima ſit Cuprum, vel aliud imperfectum metallum, dicitur conſtare ex undecim denariis; quale eſt Argentum ex quo *Ludovici* cuduntur. Argentum Anglice dictum *Sterling* conſtat ex undecim denariis, unâ cum decimâ denarii parte; ſive Cuprum eſt ad Argentum ut 3 : 37, in Monetâ noſtrâ.

15 Argentum vel ſulphuratum, vel præcipitatum vel integrum, cum Vitro cryſtallino fuſione intime mixtum, vel Cæmentatione utcunque conjunctum, colorem flavum ei ſemper impertit.

## C A P. XIV.

*De Auro sive Sole.*

1 **A**URUM est Metallum perfectissimum, coloris inter fulvum et subflavum varii; cæteris metallis, plumbo et stanno exceptis, minus elasticum, durum, et sonorum; plumbo, stanno, et argento minus fusile; fixitate, pondere, et ductili extensione omnia exsuperans; actione aëris et aquæ mutabile.

2 Aurum in igne vèhementissimo furni vitriarii per plures hebdomadas liquefactum, nullam aut calcinationem aut partium dissipationem patitur: ab igne solari condensato, in auras dissipatur, at nec in vitrum violacei coloris nec in partes dissimiles, ab illo etiam ignis gradu, converti videtur.

3 Aurum in igne candescens funditur, fustum colorem cæruleo-viridem induit, cæteris metallis mole magis augeri videtur; non satis fustum vel subito nimis refrigeratum, fit malleo  
paullò

paullò intractabilius, at a carbonum vaporibus fragile non redditur.

4 Auri filum cylindricum, cujus diameter decimæ parti unciaæ æqualis est, sustinere pòtest pondo 500.

5 Aurum cum Borace fustum, fit solito pallidius, refusum cum nitro colorem suum recuperat.

6 Posito quod gravitas specifica aquæ distillatæ et ad gradum 53<sup>m</sup> Therm. Fahren<sup>i</sup>. calefactæ sit 1,000, gravitas specifica auri purgatissimi haberi pòtest 19,376.

7 Auri reliquorumque metallorum etiam purissimorum gravitates specificæ intra certos limites variæ erunt, propter et diversam gravitatem absolutam, et diversam expansionem aquæ, quâ in diversis locis et diversâ cæli temperie ponderantur.

8 Aurum cum omnibus substantiis metallicis per fusionem commisceatur.

9 Mixtura auri et ferri in minori fluit ignis gradu, quam ferrum ipsum, et inde fit idonea ad ferri fracturas ferruminandas.

10 Mixtura auri et cupri fusilior est quam aut aurum aut cuprum, et inde utrique fit idoneum ferrumen.



11 Aurum cum Substantia quacunque Metallica colliquatum fit minus ductile ; ab Argento et Cupro malleabilitas ejus minimè diminuitur, maxime autem vel potius aufertur per parvis quantitibus Plumbi aut Stanni, vel etiam si vaporibus solum, quos fusa emittunt, bilance non dignoscendis sit expositum.

12 Aurum ut moneta fiat, atque ut aliis usibus Oeconomicis inserviat, durius reddi solet mixturâ parvarum quantitatum aliorum metallorum, Argenti præcipue et Cupri, vel amborum conjunctim.

13 Massa quælibet auri in partes viginti quatuor, quas Ceratia vocant, dividi semper concipitur ; et dicitur Aurum obryzum ; Aurum caraticum tria et vicenarium, ut Aurum Ducatorum ; Aurum caraticum duo et vicenarium, ut Aurum in Anglia dictum *Standard*, et sic deinceps, prout Aurum sit ab omni mixtura heterogenea illibatum, vel una, duabus, et sic deinceps partibus vigesimis quartis alterius alicujus metalli inquinatum.

14 Aurum,



14 Aurum, in integro suo et naturali statu, hucusque solubile nonprehenditur ab ullo acido simplici, sulphure, alkali fixo vel volatili: sed ab aqua regia, et hepate sulphuris dissolvi potest.

15 Aurum cum Argento colliquatum, ab acido marino, debita si adhibeatur Encheiresis, dissolvi dicitur.

16 Aurum in aqua regia solutum, et exinde per Alkali fixum præcipitatum, ab omnibus acidis tum mineralibus tum vegetabilibus dissolvi potest, nec non a sale Alkalino volatili, et fixo, qui conficitur methodo in propositione 6<sup>a</sup> de Argento explicata.

17 Aurum ab aqua regia per Alkali fixum aut volatile dejectum, et leni calore siccatum, vocatur *Aurum fulminans*, eo quod sive ab igne sive affricu incalescat, cum magno fragore in auras dissipatur: Hanc autem fulminandi vim, nisi Alkali volatile vel in confectione aquæ regię vel in præcipitatione adhibeatur, non acquirit.

18 Pondus Auri fulminantis majus est pondere auri soluti, parte circiter quarta.

19 Aurum

19 Aurum fulminans cum displo-  
datur, cavitates imprimit laminis me-  
tallicis non nimium crassis quibus  
imponitur, vel quibus supernè pre-  
mitur, et non deorsum tantum sed  
quaquaversum vires suas exerit.

20 Vis Elastica Auri fulminantis,  
dicitur esse ad vim elasticam pulveris  
pyrii ut 64 : 1.

21 Aurum fulminans in Sphærâ  
ferreâ exactissime obturatâ inclusum,  
ac igni expositum non disploditur; in  
simili casu pulveris pyrii facta est ex-  
plosio, et sphaera simul disrupta in-  
venitur.

22 Aurum fulminans aqua sæpius  
lavatum, cum oleo vitrioli tritum, cum  
sulphure fustum, vel ab alkali fixo lixa-  
tum, vim suam fulminantem amit-  
tit.

23 Aurum nec per calcinationem  
cum vel sine additione, nec per so-  
lutionem in aqua regia, nec per sub-  
limationem, nec per explosionem, nec  
per ullam aliam methodum hucus-

que repertam, in partes dissimiles resolvatur.

24 Aurum in aqua regia solutum cutem et plures substantias animales ac vegetabiles rubro vel purpureo colore tingit, debita facta evaporatione, in crystallos concrescit rubras, et quacunq[ue] methodo, metallico suo aspectu sit privatum, et ad pulveris speciem redactum, colorem magis minusve rubicundum plerumque adipiscitur.

25 Aurum, metallorum densissimum, cum vitro puro crystallino colliquefactione confusum, vitri densitatem adaugendo, aptum illud reddit ad reflectendos radios minime refrangebiles, et semper vitrum præbet rubro colore pellucidum.

26 Aurum a menstruo suo extrahitur atque per aliquod tempus suspensum tenetur Oleis Essentialibus; facillime autem separatur Æthere vitriolico, et cum unicum sit metallum cui hæc proprietas competit, si cum cæteris vel minima quantitate commisceatur, hoc indicio deprehendi potest.

27 Aurum in aqua regia solutum inde præcipitari potest (si multa aqua diluatur solutio) vel laminis Stanni, vel solutione Stanni in eodem menstruo factâ, sub forma pulveris coccinei qui vulgo vocatur *Cassii purpureum Magisterium*.

28 Una Auri solutionis guttula, per aliquot aquæ uncias diffusa, Stanni interventu colorem purpureum toti aquæ conciliat, et sic ab omnibus Substantiis metallicis quibus admisceatur, facillime dignoscatur.

29 Hepar Sulphuris cum Auro liquatum illud facile et adeo penitus dissolvit, ut Aurum una cum Hepate filtrum permeans, in aqua suspensum maneat.

30 Aurum ab omnibus metallicis substantiis, Platina excepta, optime purgatur fusione cum Antimonio; ab omnibus præter Argentum et Platinam cupellatione cum plumbo; ab Argento solutione in aqua regia; a Platina et minutis portiunculis cupri aliorumve metallorum quæ Catini ci-



nericii vim haud raro effugiunt, per præcipitationem ab aqua regia inter-ventu vitrioli viridis.

## C A P. XV.

### *De Platina sive Auro albo.*

**P**LATINA est metallum perfectum, fixitate, ductilitate, et gravitate specifica auro vix secunda; cæteris metallis in igne longe minus fusilis, et ferro forsan excepto durior; colore argento obfuscatò similis.

2 Platina, in igne vehementissimo quem furni et crucibula optima sustinere possunt anteaquam in vitrum liquefcunt, non funditur, sed pondere aliquantulùm augmentatur: Hæc ponderis augmentatiõ, adhæsioni forsan ferri vel metalli cujuslibet imperfecti, quod per calcinationem pondere auge-  
tur, referri debet.

3 Platina, radiis solaribus condensatis in foco speculi concavi cujus diameter



meter æqualis erat 22 unciis et focalis distantia 28 unciis, exposita ex parte in fumum erat acta, ex parte fusa in corpus album, splendescens, admodum malleabile.

4 Platina non solvitur ab acido vitriolico aquoso aut concentrato, frigido aut ebulliente; nec ab acido marino viâ aut humidâ aut siccâ; nec ab acido nitri communi aut fumante; nec a sulphure communi, nec ab ammonio crudo, et hinc ab omnibus substantiis metallicis, auro excepto, distinguitur.

5 Platina ab aqua regia et hepate sulphuris, instar auri, dissolvi potest.

6 Platina in aqua regia soluta est coloris aurei, aut fusci in rubedinem vergentis, prout solutio est ex parte vel penitus saturata: Hæc solutio evaporatione concrevit in crystallos rubentes; solidis animalium partibus, lamellis vel solutioni stanni colorem rubrum aut purpureum, lavatione aquæ haud eximendum, non impertit; a sale ammoniaco ex parte præcipitatur Platina, sed nec a vitriolo viridi, nec ab Alkali

Alkali fixo minerali; ab Oleis essentialibus, Æthere vitriolico, aut Spiritu Vini rectificato a menstruo suo non separatur, et hinc ab ipso auro distinguatur; minimaque hujus vel illius metalli portiuncula, in mixtura quavis metallica ex ambobus conflata, his præcipue similibusque indicibus facillime dignoscatur.

7 Platina ab aqua regia per Alkali volatile præcipitata, exsiccata et igni exposita non fulminat, et sic etiam ab auro discrepat.

8 Platina a menstruo suo præcipitata, cum vitro contuso mixta, et igni violentiori per longum tempus exposita, nec cum vitro fusione conjungi, nec colorem ullum ei communicare videtur.

9 Platina cum omnibus substantiis metallicis per fusionem coit: si cum Aurichalci pari pondere fundatur, massa conflabitur dura quidem et fragilis, quæ polituram eximiam suscipit, et nitorem suum diu conservat.

10 Platina cum Plumbo aut Bismutho fusa, et cupello subjecta, igne  
vix

vix vehementiffio ab istis metallis, adeo penitus liberari potest, ut fiat malleabilis.

11 Aurum cum Platina colliquatum, fit durius et in igne simul minus fusile, quod in mixtione sua cum aliis metallis non evenit.

12 Mercurius qui maiorem habet Affinitatem cum Auro et Argento quam cum Plumbo, habet etiam maiorem cum Platina; sed minorem cum Platina quam cum Auro.

13 Platina maiorem habet Affinitatem cum plumbo quam cum ferro.

14 Platina Auri instar minorem habet Affinitatem cum aqua regia quam aut Zincum, aut Ferrum, aut Cuprum, aut Stannum, aut Argentum vivum.

F I N I S.









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