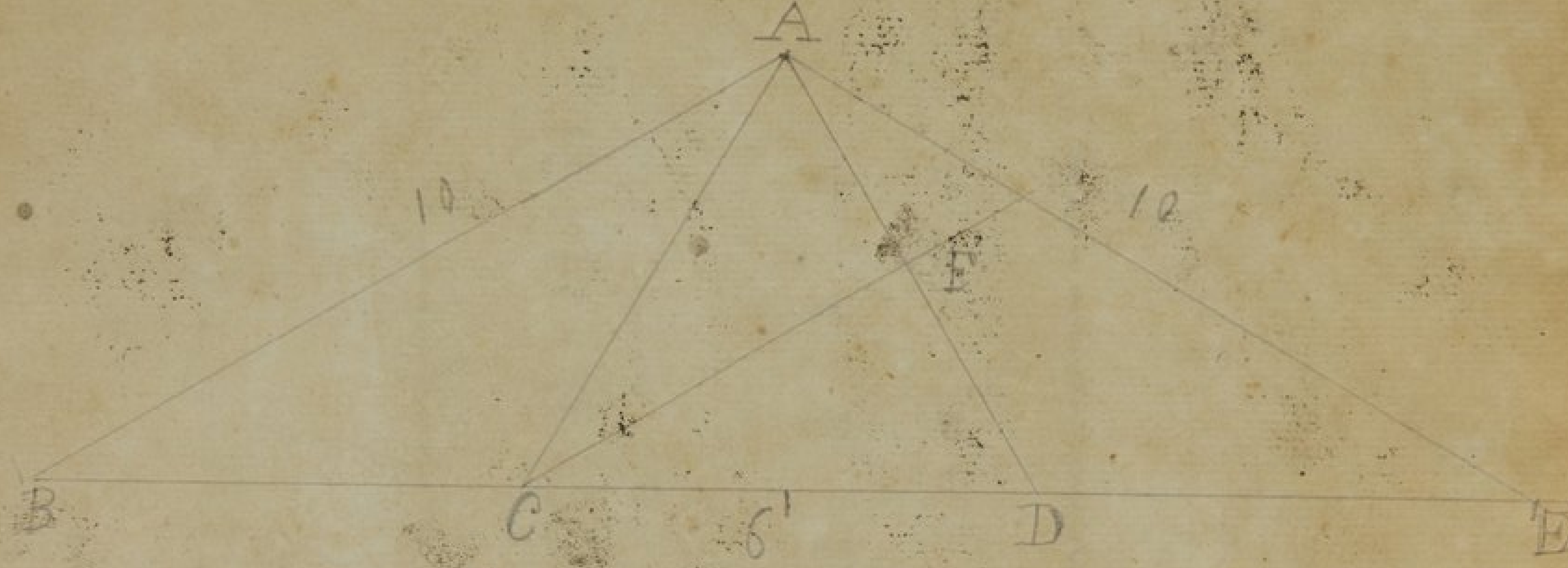
(Chemistry)



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A SYSTEM OF CHEMISTRY.

A

SYSTEM

OF

CHEMISTRY:

COMPREHENDING THE

HISTORY, THEORY, AND PRACTICE

OF THE

SCIENCE,

ACCORDING TO THE LATEST DISCOVERIES AND IMPROVEMENTS.

ILLUSTRATED WITH COPPERPLATES.

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M,DCC,XCI.

HISTORY OF CHEMISTRY.

1 Definition. CHEMISTRY may be defined, The study of such phenomena or properties of bodies as are discovered by variously mixing them together, and by exposing them to different degrees of heat, alone, or in mixture, with a view to the enlargement of our knowledge in nature, and to the improvement of the useful arts: or, It is the study of the effects of heat and mixture upon all bodies, whether natural or artificial, with a view to the improvement of arts and natural knowledge.

2 Antiquity. The science of chemistry is undoubtedly of very high antiquity; and, like most other sciences, its origin cannot be traced. In scripture, Tubal Cain, the 8th from Adam, is mentioned as the father or instructor of every artificer in brass or iron. This, however, does not constitute him a chemist, any more than a founder or blacksmith among us has a right to that title. The name of chemist could only belong to him, whoever he was, who first discovered the method of extracting metals from their ores; and this person must necessarily have lived before Tubal Cain, as every blacksmith or founder must have metals ready prepared to his hand. Nevertheless, as Tubal Cain lived before the flood, and the science of chemistry must have existed before his time, some have conjectured, that the metallurgic part, on account of its extreme usefulness to mankind, was revealed to Adam by God himself.

3 Science founded. Be this as it will, *Siphoas*, an Egyptian, is considered by the chemists as the founder of their science. He was known by the Greeks under the name of *Hermes*, or *Mercurius Trismegistus*; and is supposed to have lived more than 1900 years before the Christian æra. A numerous list of this philosopher's works is given by Clemens Alexandrinus; but none of them are now to be found, nor do any of them appear to have been written professedly on chemistry.

Two illustrious Egyptians, of the name of Hermes, are recorded by ancient authors. The elder supposed to be the same with *Mizraim*, the grandson of Noah, the *Hermes* of the Greeks, and *Mercury* of the Romans. The younger Hermes lived a thousand years afterwards; and is supposed to have restored the sciences after they had fallen into oblivion, in consequence of an inundation of the Nile. No less than 36,000 books are said to have been written under the name of Hermes; but, according to Jamblichus, a custom prevailed of inscribing all books of science with the name of Hermes. Some authors deny the existence of Hermes, and maintain that his history is allegorical.

As the science of chemistry is supposed to have been well known to the Egyptians, Moses, who was skilled in their wisdom, is thence ranked among the number of chemists; a proof of whose skill in this science is thought to be, his dissolving the golden calf made by the Israelites, so as to render it potable. 4 Moses supposed to be skilled in chemistry.

Of all the Greeks who travelled into Egypt in order to acquire knowledge, Democritus alone was admitted into their mysteries. The Egyptian priests are said to have taught him many chemical operations; among which were the arts of softening ivory, of vitrifying flints, and of imitating precious stones. Dr Black, however, is of opinion, that Democritus knew nothing more of these arts than that of making a coarse kind of glass, as no mention is particularly made of his imitating any other precious stone than the emerald, whose colour is green; and the coarser the glass the greener it is.

After the time of Democritus, we may know that considerable improvements were made in chemistry, as physicians began to make use of metallic preparations, as ceruse, verdegris, litharge, &c. Dioscorides describes the distillation of mercury from cinnabar by means of an *embic*, from which, by adding the Arabic *Al*, comes the term *Alembic*. 5 Derivation of the word Alembic. The art of distillation, however, at that time was in a very rude state; the operation being performed chiefly by separating the air, and more subtle part of tar, from the rest of the matter. 6 Original method of distilling. This was done by putting the matter to be distilled into a vessel, the mouth of which was covered with a wet cloth; and by this the steams of ascending vapour were condensed, which were afterwards procured by wringing out the cloth. No other distillation, besides this kind, is mentioned by Galen, Oribasius, Ælian, or Paulus Ægineta.

The precise time is not known when the three mineral acids were first discovered; though, as no mention is made of them by Geber, Avicenna, or Roger Bacon, it is probable that they were not known in the 12th century. Raymond Lully gives ſome hints of his being acquainted with the marine acid; whence it is probable, that it was diſcovered towards the end of the 13th, or beginning of the 14th century.

7 **Pliny's account of the origin of glaſs-making.**

Several chemical facts are related by Pliny, particularly the making of glaſs, which he aſcribes to the following accident. "Some merchants in the Levant, who had nitre on board their ſhip, having occaſion to land, lighted a fire on the ſand in order to prepare their food. To ſupport their veſſels they took ſome of the lumps of nitre with which their ſhip was loaded: and the fire acting on theſe, melted part of them along with the ſand, and thus formed the tranſparent ſubſtance called glaſs, to the great ſurpriſe of the beholders." But it is probable, that the art of glaſs-making was known long before; and it is by no means likely that it took its riſe from ſuch an accident.

8 **Alchemy firſt mentioned by Firmicus Maternus.**

The next traces we find of chemiſtry are to be extracted from the extravagant purſuits of the *Alchemiſts*, who imagined it poſſible to convert the baſer metals into gold or ſilver. The firſt mention we find of this ſtudy is by Julius Firmicus Maternus, who lived in the beginning of the fourth century, and ſpeaks of it as a well known purſuit in his time. Æneas Blaſius, who lived in the fifth century, likewiſe ſpeaks of it; and Suidas explains the term by telling us, that it is the art of making gold and ſilver. He tells us, that Diocleſian, when perſecuting the Chriſtians, forbad all chemical operations, leſt his ſubjects ſhould diſcover the art of making gold, and thus be induced to rebel againſt him.

9 **Origin of the fable the Argonauts.**

He ſuppoſes alſo, that the Argonautic expedition was only an attempt to procure a ſkin or parchment, on which was written the *recipe* for making gold. It is a common practice, however, in ſome places where gold is waſhed down in ſmall particles by brooks and rivulets from the mountains, to ſuſpend in the water the ſkins of animals having wool or hair upon them, in order to detain the heavier particles which contain the gold; and this probably gave riſe to the fable of the golden fleece. Suidas, however, who lived as late as the tenth century, deſerves very little credit, eſpecially as alchemy is not mentioned by any ancient author.—The Arabian phyſicians afford the moſt clear and diſtinct evidence concerning alchemy. Avicenna, who lived in the tenth century, is ſaid by a diſciple of his to have wrote upon alchemy; he mentions alſo roſe-water, and ſome other chemical preparations; and in the 12th century we find phyſicians adviſed to cultivate an acquaintance with the chemiſts; and another of the Arabian writers ſay, that the method of preparing roſe water, &c. was then well known.

10 **Alchemy firſt ſuppoſed to be derived from the Arabians.**

—From this evidence of the exiſtence of alchemy among the Arabians, with the prefatory article *Al*, to denote the greatneſs of the ſcience, it has been conjectured, that the doctrine of the tranſmutation of metals firſt took its riſe among the Arabians, and was introduced into Europe by means of the Cruſades, and by the rapid conqueſts of the Arabians themſelves in Europe as well as in Aſia and Africa. Europe at that time had been in a ſtate of the greateſt barbarity from the incurſions of the northern nations; but the Arabians contributed to revive ſome of the ſciences, and introduced alchemy among the reſt, which continued till the middle of the 17th century; at which time the extravagance of its profeſſors roſe to the greateſt height.

11 **No credit due to the doctrine of tranſmutation.**

Though the pretenſions of the alchemiſts are now univerſally refuted, yet from ſome of the diſcoveries which have been made in chemiſtry, we are even yet in danger of giving ſome credit to the poſſibility of the proceſs of tranſmutation. When we conſider that the metals are bodies compounded of parts which we can take away and reſtore, and that they are cloſely allied to one another in their external appearance, we may be inclined to think favourably even of the projects of the alchemiſts. The very ſeparation of the metals from their ores, the depriving them of their ductility and malleability, and the reſtoration of theſe properties to them at pleaſure, will appear very ſurpriſing to thoſe who are unacquainted with chemiſtry.

12 **Quickſilver produced from lead.**

There are alſo proceſſes of the more difficult kind, by which quickſilver may be produced from metals that are commonly ſolid, as from lead. Some of theſe we find in Boerhaave, Boyle, &c. authors of the greateſt credit, who both ſpeak of the operation and product as realities of which they were convinced by their own experience. Theſe have been urged, not without ſome plauſibility, in favour of the tranſmutation of the imperfect metals into gold; and hence the deluſions of alchemy were not confined to the vain, the ignorant, and the ambitious part of mankind; but many ingenious and learned men, who took pleaſure in the ſtudy of nature, have been ſeduced into this unhappy purſuit. This happened chiefly in Germany, where the variety of mines naturally turned the thoughts of chemiſts principally towards the metals, though the numerous failures of thoſe who had attempted this art ought to have taught them better.

About the beginning of the 16th century, the pretenders to alchemy were very numerous, and a multitude of knaves, who had beggared themſelves in the attempt, now went about to enſnare others, performing legerdemain tricks, and cauſing people believe that they could actually make gold and ſilver. A number of the tricks they made uſe of are to be met with in Lemery. Many books, with the ſame deſign of impoſing upon mankind, were written upon the ſubject of alchemy. They aſſumed fictitious names of the greateſt antiquity, and contained rules for preparing the philoſopher's ſtone; a ſmall quantity of which thrown into a baſe metal ſhould convert the whole into gold. They are wrote in a myſterious ſtyle, without any diſtinct meaning; and though ſometimes proceſſes are clearly enough deſcribed, they are found to be falſe and deceitful upon trial, the products not anſwering the pretenſions of the authors. Their excuſe was, that it was vain to expect plain accounts of theſe matters, or that the books on theſe ſubjects ſhould be written diſtinctly and clearly; that the value of gold was in proportion to its ſcarcity, and that it might be employed to bad purpoſes: they wrote only for the laborious and judicious chemiſts, who would underſtand them provided they made themſelves acquainted with the metals by ſtudy and experience. But in fact, no diſtinct meaning has ever been obtained, and the books have only ſerved to delude and betray a great number of others into the loſs of their *lives*.

But though the alchemiſts failed in the execution of their

13 Chemistry derived some advantages from the labours of the alchemists.

their grand project, we must still own ourselves indebted to them for many discoveries brought to light during the time they vainly spent their labour in the expectation of making gold. Some of these are the methods of preparing spirit of wine, aquafortis, volatile alkali, vitriolic acid, and gun-powder. Medicine too was indebted to them for several valuable remedies; whence also it appears that many, who had wasted their time in the vain pursuit of the philosoper's stone, thought of trying some of their most elaborate preparations in the cure of diseases; and meeting with some success, they presumed that diseases were only to be cured by the assistance of chemistry; and that the most elaborate of all its preparations, the philosopher's stone, would cure all diseases. Some cures they performed did indeed awaken the atttention of physicians; and they introduced the use of opium, which had formerly been accounted poisonous. They succeeded also in the cure of the venereal disease, which had lately made its appearance, and baffled the regular physicians; but the chemists, by giving mercury, put a stop to its ravages, and thus introduced this valuable article into the materia medica.

14 of Paracelsus.

The most famous of the chemical professors was Paracelsus, well known for his arrogance, absurdity, and profligacy. He was bred to the study of medicine; but becoming acquainted with the alchemists, travelled about in the character of a physician, and was at great pains to collect powerful medicines from all quarters. These he used with great freedom and boldness. His success in some cases operated so upon the natural arrogance and self-sufficiency of his disposition, that he formed a design of overturning the whole system of medicine, and supplying a new one from chemistry: and indeed he found but very weak adversaries in the subtle theories of Galen with the refinements of the Arabian physicians, which only prevailed in his time; and he no doubt had some share in banishing that veneration which had been so long entertained for these celebrated personages.

15 History of chemistry since the time of Paracelsus.

16 The science studied by Lord Verulam;

From the time of Paracelsus, chemistry began every where to assume a new face. In Great Britain, Lord Verulam amused himself at his leisure hours with forming plans for promoting the sciences in general, especially those which related to the study of nature. He soon found that chemistry might turn out one of the most useful and comprehensive branches of natural philosophy, and pointed out the means of its improvement. A number of experiments were proposed by him; but he observed, that the views of chemists were as yet only adapted to explain their particular operations on metals; and he observed, that, instead of the abstruse and barren philosophy of the times, it was necessary to make a very large collection of facts, and to compare them with each other very maturely and cautiously, in order to discover the common causes and circumstances of connection upon which they all depend. He did not, however, make any considerable discoveries, and his works are tedious and disagreeable to the reader.

17 And by Mr Boyle.

A superior genius to Lord Verulam was Mr Boyle, who was born the very day that the former died. His circumstances were opulent, his manners agreeable; he was endowed by nature with a goodness of heart; and his inclination led him entirely to the study of nature, which he was best pleased with cultivating in the way of experiment. He considered the weight, spring, and qualities of the air; and wrote on hydrostatics and other subjects: and was possessed of that happy penetration and ingenuity so well suited to the making of experiments in philosophy, which serves to deduce the most useful truths from the most simple and semingly insignificant facts. As chemistry was his favourite science, he spared no pains to procure from chemists of greatest note the knowledge of curious experiments, and entertained a number of operators constantly about him. His discoveries are related in an easy style: and though rather copious, suited to the taste of the times in which he lived, and free from that absurd and mysterious air which formerly prevailed in chemical writings: nor does he betray a design of concealing any thing except some particulars which were communicated to him under the notion of secrecy, or the knowledge of which might do more harm than good. It is objected indeed, that he betrays a good deal of credulity with regard to facts which are given on the faith of others, and which may seem incredible; but this proceeded from his candour, and his being little disposed to suspect others. He showed the necessary connection between philosophy and the arts; and said, that by attending the shop of a workman, he learned more philosophy than he had done in the schools for a long time Thus his writings showed an universal taste for the study of nature, which had now made some advances in the other parts of the world.

18 Chemistry emerges from its obscurity.

Agricola is one of the first and best authors on the subject of metallurgy. Being born in a village in Missnia, a country abounding in mines and metallurgic works, he described them exactly and copiously. He was a physician, and cotemporary with Paracelsus, but of a character very different. His writings are clear and instructive, as those of Paracelsus are obscure and useless. Lazarus Erker, Schinder, Schlutter, Henkel, &c. have also written on metallurgy, and described the art of assaying metals. Anthony Neri, Dr Merret, and the famous Kunckel (who discovered the phosphorus of urine), have described very fully the arts of making glass, enamels, imitations of precious stones, &c.: but their writings, as well as those of succeeding chemists, are not free from the illusionsof alchemy; so true it is, that an obstinate and inveterate malady never disappears at once, without leaving traces behind. In a short time, however, the alchemical phrenzy was attacked by many powerful antagonists, who contributed to rescue the science of chemistry from an evil, which at once disgraced it and retarded its progress. Among these, the most distinguished are Kircher a Jesuit, and Conringius a physician, who wrote with much success and reputation.

19 Royal Society how founded,

About the year 1650 the Royal Society was formed by a number of gentlemen who were unwilling to engage in the civil wars; and being struck with the extensive views of Lord Verulam and Mr Boyle, contributed to the expence of costly experiments. This example appeared so noble, and the design so good, that it has been followed by all the civilized states of Europe, and has met with the protection of their respective sovereigns; and from these chemistry has received considerable improvements. In France, Geoffroy, Lemery, Reaumur, &c. came to be distinguished;

ed; and in Germany Margraaf, Pott, and others, have made a conſiderable figure in thoſe ſocieties. Kunckel, Begar, Stahl, and Hoffman, &c. have done great ſervice to ſociety, by introducing new arts, and the numerous improvements they have made.

20 Of the improvements made by different nations in chemiſtry.

The chemiſts who have made a figure in Germany and France are more in number than thoſe whom Britain has produced. In France, the ſociety was encouraged by the ſovereign; and in it they have diveſted themſelves of that myſterious air which was affected in former ages. In Germany, the richneſs of the country, and the great variety of mines, by turning the attention of chemiſts to the metals, have given that alchymiſtical air to their writings which we obſerve in them. The number of thoſe who have applied themſelves to chemiſtry is very ſmall in England, owing to the great improvements made by Sir Iſaac Newton in the ſciences of aſtronomy and optics; which, by turning the general attention that way, has occaſioned what may be called a neglect of chemiſtry. But if their number be inconſiderable, they are by no means inferior in merit and fame. The name of Boyle has always been held in the higheſt eſteem, as well as that of Hales, for the analyſis he has made of the air. Sir Iſaac Newton alone has done more to the eſtabliſhing a rational chemical theory than ever was done before. Of late, the taſte for the ſtudy has became more general, and many uſeful books have appeared; ſo that it is to be hoped they will ſoon excel in this branch of ſcience, as they have done in all the reſt.

THEORY

THEORY OF CHEMISTRY.

PART I.

21 Perfect Theory, what.

ACCORDING to the definition we have given of this science, the theory of it ought to consist in a thorough knowledge of all the phenomena which result from every possible combination of its objects with one another, or from exposing them in all possible ways to those substances which chemists have found to be the most active in producing a change. So various, however, and so widely extended are the objects of chemistry (comprehending all terrestrial bodies whatever), that a knowledge of this kind is utterly unattainable by man. The utmost that can be done in this case is, to give some account of the phenomena which accompany the mixtures of particular substances, or the appearances they put on when exposed to heat; and these have been already so well ascertained, that they may now be laid down as rules, whereby we may, with a good deal of certainty, judge of the event of our experiments, even before they are made.

22 Objects of Chemistry, what.

Here we must observe, that though the objects of chemistry are as various as there are different substances in the whole system of nature, yet they cannot all be examined with equal ease. Some of these substances act upon others with great violence; and the greater their activity, the more difficultly are they themselves subjected to a chemical examination. Thus, fire, which is the most active body in nature, is so little the subject of examination, that it hath hitherto baffled the ingenuity of the greatest philosophers to understand its composition. This substance, therefore, though it be the principal, if not the only *agent* in chemistry, is not properly an *object* of it, because it cannot be made a subject of any chemical operation.

23 Supposition of elements the origin of alchemy.

It hath been customary to consider all bodies as composed of certain permanent and unchangeable parts called *elements*; and that the end of chemistry was to resolve bodies into these elements, and to recompose them again by a proper mixture of the elements when so separated. Upon this supposition the alchemists went; who, supposing that all bodies were composed of salt, sulphur, and mercury, endeavoured to find out the proportions in which these existed in gold, and then to form that metal by combining them in a similar manner. Had they taken care to ascertain the real existence of their elements, and, by mixing them together, composed any one metal whatever, though but a grain of lead, the least valuable of them all; their pretensions would have been very rational and well founded; but as they never ascertained the existence of such elementary bodies, it is no wonder that their labours were never attended with success.

24 Mr Boyle's opinion.

Another set of elements which were as generally received, and indeed continue to be so in some measure to this day, are fire, air, earth, and water.—This doctrine of elements was strenuously opposed by Mr Boyle; who endeavoured to prove, that fire was not an element *per se*, but generated merely from the motion of the particles of terrestrial bodies among one another; that air was generally produced from the substance of solid bodies; and that water, by a great number of distillations, was converted into earth. His arguments, however, concerning fire were not at all conclusive; nor does the expulsion of air from fixed bodies prove that any of their solid parts were employed in the composition of that air; as later discoveries have shown that air may be absorbed from the external atmosphere, and fixed in a great number of solid substances. His assertion concerning water deserves much consideration, and the experiment is well worth repeating; but it does not appear that he, or any other person, ought to have relied upon the experiment which was intended to prove this transmutation. The fact was this. Having designed to try the possibility of reducing water to earth by repeated distillations, he distilled an ounce of water three times over himself, and found a small quantity of earth always remaining. He then gave it to another, who distilled it 197 times. The amount of earth from the whole distillations was six drams, or $\frac{3}{4}$ths of the quantity of water employed; and this earth was fixed, white, and insoluble in water.—Here it is evident, that great suspicions must lie against the fidelity of the unknown operator, who no doubt would be wearied out with such a number of distillations. The affair might appear trivial to him; and as he would perhaps know to which side Mr Boyle's opinion inclined, he might favour it, by mixing some white earth with the water. Had the experiment been tried by Mr Boyle's own hand, his known character would have put the matter beyond a doubt.

The decomposition of water, however, in another way, by the combination of one part of it with the

philophlogiftic, and another with the earthy part of a metal, is now well afcertained, and the experiments which led to the difcovery are treated of under the articles Aerology and Water.

25 Exiftence of elements difputed. Even the exiftence of earth as an element appears as dubious as that of the others; for it is certain that there is no fpecies of earth whatever, from which we can produce two diffimilar bodies, by adding their other component parts.—Thus, the earth of alum has all the characters of fimplicity which we can defire in any terreftrial fubftance. It is white, infipid, inodorous, and perfectly fixed in the fire; neverthelefs, it feems to be only an element of that particular body called *alum*; for though alum is compofed of a pure earth and vitriolic acid joined together, and Epfom falt and felenite are both compofed of a pure earth combined with the fame acid; yet by adding oil of vitriol to the earth of alum, in any poffible way, we fhall never be able to form either Epfom falt or felenite. In like manner, though all the imperfect metals are compofed of inflammable matter joined with an earthy bafis; yet by adding to earth of alum any proportion we pleafe of inflammable matter, we fhall never produce a metal; and what is ftill more mortifying, we can never make the earthy bafis of one metallic fubftance produce any other metal than that which it originally compofed.

26 Elements neceffarily invifible. A little confideration upon the fubject of elements will convince us, not only that no fuch bodies have ever yet been difcovered, but that they never will; and for this plain reafon, that they muft be in their own nature invifible.—The component parts of any fubftance may with propriety enough be called the elements of that fubftance, as long as we propofe carrying the decompofition no farther; but thefe elements have not the leaft property refembling any fubftance which they compofe. Thus, it is found that the compound falt called *fal ammoniac*, is formed by the union of an acid and an alkali: we may therefore properly enough call thefe two the elements of fal ammoniac; but, taken feparately, they have not the leaft refemblance to the compound, which is formed out of them. Both the acid and alkali are by themfelves fo volatile as to be capable of diffipation into an invifible vapour by the heat of one's hand; whereas, when joined together, they are fo fixed as almoft to endure a red heat without going off. If, again, we were to feek for the elements of the acid and alkali, we muft not expect to find them have any properties refembling either an acid or an alkali, but others quite different. Any common element of all bodies muft therefore be a fubftance which has no property fimilar to any other in the whole fyftem of nature, and confequently muft be imperceptible.

27 Suppofition concerning phlogifton. To the abovementioned four elements, viz. fire, air, earth, and water, a kind of *fifth* element has generally been added, but not ufually diftinguifhed by that name, though it has apparently an equal, if not a greater, right to the title of an *element* than any of the others. This fubftance is called the *phlogifton*, or inflammable principle; on which the ignition of all bodies depends. The exiftence of this element was firft afferted by Stahl, and from him the opinion has been derived to other chemifts: but of late a new doctrine was broached by M. Lavoifier, who denies the exiftence of phlogifton altogether. Though none of thefe fubftances therefore are properly the objects of chemiftry, yet as they have fo much ingroffed the attention of modern chemifts, we fhall here give an account of the moft remarkable theories that have appeared concerning them.

Of the Element of Fire.

Sect. I. *Of the Element of Fire.*

The opinions concerning the element of fire may be divided into two general claffes; the one confidering it as an effect, the other as a caufe. The former is maintained by Lord Bacon, Mr Boyle, and Sir Ifaac Newton; whofe refpectable names for a long time gave fuch a fanction to this theory, that it was generally looked upon as an eftablifhed truth. Some learned men, however, among whom was the great Dr Boerhaave, always diffented, and infifted that fire was a fluid univerfally diffufed, and equally prefent in the frozen regions of Nova Zembla as in a glafs-houfe furnace, only that in the latter its motion made it confpicuous; and by fetting it in motion in the coldeft parts of the world, its previous exiftence there would be equally demonftrable as in the furnace abovementioned. 28 Two general theories of heat.

29 Lord Bacon's definition of heat. Lord Bacon defines heat, which he ufes as a fynonymous term with fire, to be an expanfive undulatory motion in the particles of a body, whereby they tend with fome rapidity towards the circumference, and alfo a little upwards. Hence, if in any natural body you can excite a motion whereby it fhall expand or dilate itfelf, and can reprefs and direct this motion upon itfelf in fuch a manner that the motion fhall not proceed uniformly, but obtain in fome parts and be checked in others, you will generate heat or fire.

30 Mr Boyle's opinion. The fame opinion is fupported by Mr Boyle in the following manner: "The production of heat difcovers nothing, either in the agent or patient, but motion, and its natural effects. When a fmith brifkly hammers a fmall piece of iron, the metal thereby becomes exceedingly hot: yet there is nothing to make it fo, except the motion of the hammer impreffing a vehement and varioufly determined agitation on the fmall parts of the iron; which, being a cold body before, grows hot by that fuperinduced motion of its fmall parts: firft, in a more loofe acceptation of the word, with regard to fome other bodies, in comparifon of which it was cold before; then fenfibly hot, becaufe the motion in the parts of the iron is greater than that in the parts of our fingers; at the fame time that the hammer and anvil, by which the percuffion is communicated, may, on account of their magnitude, remain cold. It is not neceffary, therefore, that a body fhould itfelf be hot in order to communicate heat to another."

31 Sentiments of Sir Ifaac Newton. The arguments made ufe of by Sir Ifaac Newton are not intended pofitively to eftablifh any kind of theory relating to fire, but are to be found in a conjecture, publifhed at the end of his Treatife on Optics, concerning the nature of the fun and ftars. "Large bodies (he obferves) preferve their heat the longeft, their parts heating one another; and why may not great, denfe, and fixed bodies, when heated beyond a certain degree, emit light fo copioufly, as, by the emiffion and reaction of it, and the reflections and refractions within the pores, to grow continually hotter, till they arrive at fuch a period of heat as is that of the fun? Their parts

Of the Element of Fire.

parts may be further preſerved from fuming away, not only by their fixity, but by the vaſt weight and denſity of the atmoſphere incumbent on them, ſtrongly compreſſing them, and condenſing the vapours exhaled from them. Thus we ſee, that warm water, in an exhauſted receiver, ſhall boil as vehemently as the hotteſt water expoſed to the air: the weight of the incumbent atmoſphere in this latter caſe keeping down the vapours, and hindering the ebullition till it has received its utmoſt degree of heat. Thus alſo a mixture of tin and lead, put on a red hot iron *in vacuo*, emits a fume and flame: but the ſame mixture in the open air, by reaſon of the incumbent atmoſphere, does not emit the leaſt ſenſible flame." In conſequence of theſe experiments, Sir Iſaac conjectures, that there is no eſſential diſtinction betwixt fire and groſs bodies; but that they may be converted into one another. "Fire (he ſays) is a body heated ſo hot as to emit light copiouſly; for what (ſays he) is a red hot iron but fire?"

32 Fire now generally allowed to be an element *per ſe*.

The hypotheſes of theſe great men produced long and violent diſputes, which were never deciſively ſettled: The diſcoveries in electricity, however furniſhed ſuch additional ſtrength to the followers of Dr Boerhaave, that fire is now believed to be an element and fluid diſtinct from all others, by at leaſt as many as eſpouſe the contrary ſyſtem; but the queſtion is not decided, Whether the fire itſelf is to be conſidered as the agent? or, Whether its action is to be derived from the principles of attraction and repulſion, the natural agents ſuppoſed to influence other material ſubſtances? This has produced two other ſyſtems of a kind of mixed nature, in which heat or fire is conſidered as a ſubſtance diſtinct from all others, but which acts in other bodies according to its *quantity*. Theſe ſyſtems have been promulgated by Dr Black of Edinburgh and Dr Irvine of Glaſgow. They differ from the opinions of Mr Boyle, Lord Bacon, and Sir Iſaac Newton, in ſuppoſing heat to be a fluid diſtinct from all other material ſubſtances; and they alſo differ from the hypotheſis of Dr Boerhaave, Lemery, and others, in ſuppoſing different terreſtrial ſubſtances to be hot according to the *quantity* of fluid contained, and not according to the force with which it moves in them.

33 Two other theories inſtituted.

34 In what they differ from the former.

35 General account of Dr Black's and Dr Irvine's theories.

Dr Black is of opinion that *heat*, which he ſeems to make ſynonymous with fire, exiſts in two different ſtates; in one of which it affects our ſenſes and the thermometer, in the other it does not. The former therefore he calls *ſenſible* heat, the later *latent* heat. On theſe principles he gives the only ſatisfactory explanation of the phenomena of evaporation and fluidity that has yet appeared, as ſhall afterwards be more fully explained. At preſent we ſhall only obſerve, that, according to the theory of Dr Black, heat or fire itſelf ſeems to be the agent; but, according to that of Dr Irvine, as far as we can gather it from the treatiſes of Dr Crawford and others, the principles of attraction and repulſion are the agents by which heat, as well as other bodies, is influenced. Thus, on the principles of Dr Black, we ſay, that water is converted into vapour by a quantity of heat entering into it in a *latent* ſtate, and thereby rendering it ſpecifically lighter than the atmoſphere; according to the principles of Dr Irvine, we ſay, that water is converted into vapour by having its capacity for attracting heat from the atmoſphere increaſed. So that, according to the former, the abſorption of heat is the *cauſe*; according to the latter, the *effect*, of its converſion into vapour.

36 Dr Irvine's theory explained by Dr Crawford.

Dr Crawford, in his Treatiſe on Heat, publiſhed in 1788, informs us, that *heat*, in the philoſophical ſenſe of the word, has been uſed to expreſs what is frequently called the *element of fire*, in the abſtract, without regard to the peculiar effects which it may produce in relation to other bodies. This, with Dr Irvine, he calls *abſolute* heat; and the external cauſe, as having a relation to the effects it produces, he calls *relative* heat. "From this view of the matter (ſays he), it appears, that *abſolute heat* expreſſes, in the abſtract, that *power* or *element* which, when it is preſent to a *certain* degree, excites in all animals the ſenſation of heat; and *relative* heat expreſſes the ſame power, conſidered as having a relation to the effects by which it is known and meaſured.

37 Abſolute heat defined.

38 Relative heat.

39 How divided.

"The effects by which heat is known and meaſured are three; and therefore relative heat may admit of three ſubdiviſions. 1. This principle is known by the peculiar ſenſations which it excites in animals. Conſidered as exciting thoſe ſenſations, it is called *ſenſible* heat. 2. It is known by the effect which it produces upon an inſtrument that has been employed to meaſure it, termed a *thermometer*. This is called the *temperature of heat in bodies*. 3. It has been found by experiment, that in bodies of different kinds the quantities of abſolute heat may be unequal, though the temperatures and weights be the ſame. When the principle of heat is conſidered relatively to the whole quantity of it contained in bodies of different kinds, but which have equal weights and temperatures, I ſhall term it *comparative heat*. If, for example, the temperatures and weights being the ſame, the whole quantity of heat in water be four times as great as that of antimony, the comparative heats of theſe ſubſtances are ſaid to be as four to one."

40 Comparative heat defined.

41 Experiments by which Dr Black was led to the diſcovery of latent heat.

In order to have a proper conception of what is meant by a difference in abſolute heat, when the temperatures are the ſame, it will be neceſſary to relate ſome experiments, by which Dr Black was firſt led to the diſcovery of latent heat. He obſerves, that when two equal maſſes of the ſame matter, heated to different degrees, are mixed together, the heat of the mixture ought to be an arithmetical mean betwixt the two extremes. This, however, only takes place on mixing hot and cold water together; but if inſtead of cold water we take ice, the caſe is remarkably different. Here the temperature of the mixture is much below the arthmetical mean, and a quantity of heat is apparently loſt. Now we know that the temperature of ice newly frozen is generally 32 degrees of Fahrenheit; ſuppoſing therefore the temperature of the water which diſſolves it to be 120, the arithmetical mean is 71; but if the mixture indicates a temperature only of 60°, then we muſt ſuppoſe that the ice contained 11° of heat leſs than was indicated by the thermometer; and conſequently, that water at 32° contains 11° more of abſolute heat than ice at 32°.

42 A quantity of heat loſt in the melting of ice.

43 Great quantity of heat produced by the condenſation of vapour.

The ſame thing is made ſtill more evident from the condenſation of vapour. The fluid of water is not capable of ſuſtaining a great degree of heat; and 212° of Fahrenheit is the utmoſt it can be made to bear, without an extraordinary degree of preſſure, as in Papin's

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pin's digeſter, or the admixture of ſaline ſubſtances: the temperature of the ſteam emitted by it therefore never can exceed 212°, except in the caſes juſt mentioned; and it is often capable of bearing a great degree of cold without being condenſed. When the condenſation takes place at laſt, however, a very conſiderable degree of heat is always produced; and Dr Black has ſhown, that, in the condenſation of ſteam by the refrigeratory of a common ſtill, as much heat is communicated to the water in the refrigeratory as would be ſufficient to make the water which comes over as hot as red hot-iron, were it all to exiſt in a ſenſible ſtate. His method of making the calculation is very eaſy. For, ſuppoſing the refrigeratory to contain 100 pounds of water, and that one pound has been diſtilled; if the water in the refrigeratory has received 10 degrees of heat, we know that the diſtilled pound has parted with 1000. If in paſſing through the worm of the refrigeratory, it has been reduced to the temperature of 50° of Fahrenheit, having been at 212° when it entered it, then it has loſt only 162° of ſenſible heat; all the reſt communicated to the water of the refrigeratory amounting to more than 800°, having been contained in a latent ſtate, and ſuch as could not then affect the thermometer.

44 Dr Black's method of calculating it.

45 Mr Watt's experiment on the diſtillation of water *in vacuo*.

This experiment was tried by Mr Watt in a manner ſtill more ſtriking, by a diſtillation of water *in vacuo*. Thus the ſteam, freed from the preſſure of the atmoſphere, could not conceive ſuch a degree of ſenſible heat as in the common method of diſtilling. It came over therefore with a very gentle warmth, ſcarce more than what the hand could bear; nevertheleſs it had abſorbed as much heat as though the diſtillation had been performed in the common way; for the refrigeratory had 1000 degrees of heat communicated to it.

46 Difference of abſolute heat in different fluids.

47 Thinneſt fluids contain the greateſt quantity of heat.

The difference of abſolute heat is likewiſe perceptible betwixt any two bodies of different denſity, water and mercury for inſtance: and in comparing theſe, it will always be found that the thinneſt fluids contain the greateſt quantity of abſolute heat; as water more than mercury, ſpirit of wine, more than water, ether more than ſpirit of wine, and air more than any of them. Dr Black having brought equal bulks of mercury and water, the former to a temperature of 50 degrees higher than the latter, found that, on mixture, there was a gain of only 20 degrees above the original; but on reverſing the experiment, and heating the water 50 degrees above the mercury, there was a gain of 30 degrees on the whole. "Hence (ſays Dr Cleghorn in his theſis *de Igne*) it appears, that the quantity of heat in water is to that in mercury, when both are of equal temperatures, as 3 to 2." Dr Crawford, however, tells us, that "the ſame quantity of heat which raiſes a pound of water one degree, will raiſe a pound of mercury 28 degrees; whence it follows, that the comparative heat of water is to that of mercury as 28 to 1: and conſequently, the alterations which are produced in the temperatures of bodies by given quantities of abſolute heat, may properly be applied as a meaſure of their comparative heats; the alterations of temperature and the comparative heats being reciprocally proportional to one another.

48 Great difference betwixt the calculations of Drs Cleghorn and Crawford.

49 Crawford's account of ſenſible heat.

"Senſible heat (continues Dr Crawford) depends partly on the ſtate of the temperature, and partly on that of the organ of feeling; and therefore if a variation be produced in the latter, the ſenſible heat will be different, though the temperature continue the ſame. Thus water at the temperature of 62° of Fahrenheit appears cold to a warm hand immerſed in it; but on the contrary, that fluid will appear warm if a hand be applied to it which has a lower degree of heat than 62°. For this reaſon, the thermometer is a much more accurate meaſure of heat than the ſenſes of animals. As long, however, as the organs remain unchanged, the ſenſible heat is in proportion to the temperature; and therefore thoſe terms have generally been conſidered as ſynonymous.

50 Dr Reid's obſervation concerning temperatures.

On this ſubject Dr Reid obſerves, that until the ratio between one temperature and another be aſcertained by experiment and induction, we ought to conſider temperature as a meaſure which admits of degrees, but not of ratios; and conſequently ought not to conclude, that the temperature of one body is double or triple to that of another, unleſs the ratio of different temperatures were determined. Nor ought we to uſe the expreſſions of a *double* or *triple* temperature, thoſe being expreſſions which convey no diſtinct meaning until the ratio of different temperatures be determined."

51 Difference betwixt the calculations of Drs Crawford and Black.

In making experiments on the comparative quantities of heat in different bodies, our author chooſes rather to uſe equal *weights* than equal *bulks* of the ſubſtances to be compared. Thus he found the comparative heat of water to be to that of mercury as 28 to 1 by weight, and 2 to 1 by bulk; which differs very conſiderably from the concluſion of Dr Black, who makes it only as 3 to 2, as has been already mentioned.

52 Capacities for containing heat explained.

From the differences obſerved in the quantities of abſolute heat contained in different bodies, our author concludes, that "there muſt be certain eſſential differences in the nature of bodies; in conſequence of which, *ſome* have the power of collecting and retaining that element in greater quantity than *others*." Theſe different powers he calls the *capacities* for containing heat. Thus, if we find by experiment that a pound of water contains four times as much abſolute heat as diaphoretic antimony, when at the ſame temperature, the capacity of water for containing heat is ſaid to be to that of animony as 4 to 1.

53 How the capacity, temperature, and abſolute heat, are to be diſtinguiſhed.

"The temperature, the capacity for containing heat, and the abſolute heat contained, may be diſtinguiſhed from each other in the following manner.

"The capacity for containing heat, and the abſolute heat contained, are diſtinguiſhed as a force diſtinct from the ſubject upon which it operates. When we ſpeak of the capacity, we mean a power inherent in the heated body; when we ſpeak of the abſolute heat, we mean an unknown principle which is retained in the body by the operation of this power; and when we ſpeak of the temperature, we conſider the unknown principle as producing certain effects upon the thermometer.

"The capacity for containing heat may continue unchanged, while the abſolute heat is varied without end. If a pound of ice, for example, be ſuppoſed to retain its ſolid form, the quantity of its abſolute heat will be altered by every increaſe or diminution of its ſenſible heat: but as long as its form continues the ſame, its capacity for receiving heat is not affected by an an alteration of temperature, and would remain unchanged though the body were wholly deprived of its heat."

54 Crawford's opinion concerning heat in the abſtract.

In the courſe of his work, Dr Crawford obſerves, that "he has not entered into the inquiry which has been ſo much agitated among the Engliſh, the French, and the German philoſophers, Whether heat be a *ſubſtance* or a *quality*? In ſome places indeed he has uſed expreſſions which ſeem to favour the former opinion; but his ſole motive for adopting theſe was, becauſe the language ſeemed to be more ſimple and natural, and more conſonant to the facts which had been eſtabliſhed by experiment. At the ſame time, he is perſuaded that it would be a very difficult matter to reconcile many of the phenomena with the ſuppoſition that heat is a *quality*. It is not eaſy to conceive, upon this hypotheſis, how heat can be abſorbed in the proceſſes of fuſion, evaporation, combuſtion; how the quantity of heat in the air can be diminiſhed, and that in the blood increaſed, by reſpiration, though no ſenſible heat or cold be produced.

"Whereas, if we adopt the opinion that heat is a diſtinct ſubſtance, or an element *ſui generis*, the phenomena will be found to admit of a ſimple and obvious interpretation.

55 Fire contained in bodies partly by its attraction to them, and partly by the preſſure of the external fluid.

"Fire will be conſidered as a principle; which is diſtributed in various proportions throughout the different kingdoms of nature. The mode of its union with bodies will reſemble that particular ſpecies of union, wherein the elements are combined by the joint forces of preſſure and attraction. Of this kind is the combination of fixed air and water; for fixed air is retained in water partly by its attraction for that fluid, and partly by the preſſure of the external air; and if either of theſe forces be diminiſhed, a portion of the fixed air eſcapes. In like manner, it may be conceived that elementary fire is retained in bodies, partly by its attraction to theſe bodies, and partly by the action of the ſurrounding heat; and in that caſe a portion of it will be diſengaged, either by diminiſhing the attractive force, or by leſſening the temperature of the circumambient medium. If, however, fire be a ſubſtance which is ſubject to the laws of attraction, the mode of its union with bodies ſeems to be different from that which takes place in chemical combination: for, in chemical combination, the elements acquire new properties, and either wholly or in part loſe thoſe by which they were formerly characterized. But we have no ſufficient evidence for believing that fire, in conſequence of its union with bodies, does, in any inſtance, loſe its diſtinguiſhing properties."

56 Dr Berkenhout's opinion concerning the nature of heat.

Dr Berkenhout, in his firſt Lines of the Theory and Practice of Philoſophical Chemiſtry, informs us, that "heat, or the *matter of heat*, is by Scheele and Bergman ſubſtituted for fire, which they believe to be the action of heat when increaſed to a certain degree. The firſt of theſe celebrated chemiſts believed this *matter of heat* to be a compound of phlogiſton and pure air. He was certainly miſtaken. It ſeems more philoſophical to conſider heat as an *effect*, of which fire is the ſole cauſe.

57 His diviſion of fire into fixed and volatile.

"Heat I conſider not as a diſtinct ſubſtance, but as an effect of fire, fixed or volatile; in both which ſtates fire ſeems to exiſt in all bodies, ſolid and fluid. Fixed fire I believe to be a conſtituent part of all bodies, and their ſpecific heat to depend on the quantity of fixed fire in each. This fixed, this latent fire, cannot be ſeparated from the other conſtituent parts of bodies but by their decompoſition: it then becomes volatile and incoercible. If this hypotheſis be true, fire exiſts, in all natural bodies that contain phlogiſton, in three different ſtates: 1. In that volatile ſtate in which it perpetually fluctuates between one body and another. 2. Combined with an acid, probably in the form of fixed inflammable air or phlogiſton. 3. Uncombined and fixed, as a conſtituent principle, determining the ſpecific heat of bodies.

58 Pure or volatile fire defined.

"Pure (or volatile) fire is diſtinguiſhed by the following properties. 1. It is eſſentially fluid, inviſible, and without weight. 2. It is the immediate cauſe of all fluidity. 3. It penetrates and pervades all bodies on the ſurface of the earth, and as far beneath the ſurface as hath hitherto been explored. Water hath never been found in a congealed ſtate in the deepeſt mines. 4. It has a conſtant tendency to diffuſe itſelf equally through all bodies, howſoever different in point of denſity. A marble ſlab, a plate of iron, a decanter of water, and a lady's muff, at the ſame diſtance from the fire, and other external circumſtances, being equal, poſſeſs an equal degree of heat, which is preciſely that of the atmoſphere in which they ſtand. 5. It is perpetually in motion from one body to another, and from different parts of the ſame body, becauſe external circumſtances are continually varying. 6. In fluctuating from one body to another, it produces a conſtant vibration of their conſtituent parts; for all bodies expand and contract in proportion to the quantity of fire they contain. 7. Accumulated beyond a certain quantity, it effects the diſſolution of bodies, by forcing their conſtituent parts beyond the ſphere of mutual attraction, called the *attraction of coheſion*, which is the cauſe of ſolidity. Hence the ſoveriegn agency of fire in chemical operations."

59 Dr Crawford's definition of fire.

Dr Crawford, beſides the opinions already quoted, tells us, that fire, in the vulgar acceptation of the word, expreſſes a certain degree of heat accompanied with light; and is particularly applied to that heat and light which are produced by the inflammation of combuſtible bodies. But as heat, when accumulated in a ſufficient quantity, is conſtantly accompanied with light; or, in other words, as fire is always produced by the increaſe of heat, philoſophers have generally conſidered theſe phenomena as proceeding from the ſame cauſe: and have therefore uſed the word *fire* to expreſs that unknown principle, which, when it is preſent to a certain degree, excites the ſenſation of heat alone; but, when accumulated to a greater degree, renders itſelf obvious both to the ſight and touch, or produces heat accompanied with light. In this ſenſe, the element of fire ſignifies the ſame thing with *abſolute heat*.

Having premiſed theſe general definitions and remarks, he gives the properties of heat in the following words:

60 Heat has a tendency itſelf equally over bodies.

"I. Heat has a conſtant tendency to diffuſe itſelf over all bodies till they are brought to the ſame temperature. Thus it is found by the thermometer, that if two bodies of different temperatures are mixed together, or placed contiguous, the heat paſſes from the one to the other till their temperatures become equal;

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and that all inanimate bodies, when heated and placed in a cold medium, continually lose heat, till in process of time they are brought to the state of the surrounding medium.

"From this property of heat it follows, that the various classes of bodies throughout the earth, if they were not acted upon by external causes, would at length, arrive at a common temperature when the heat would become quiescent; in like manner as the waters of the ocean, if not prevented by the winds and by the attractions of the sun and moon, would come to an equilibrium, and would remain in a state of rest. But as causes continually occur in nature to disturb the balance of heat as well as that of the waters of the ocean, those elements are kept in a constant fluctuation.

61 It is contained in considerable quantity in all bodies.

"II. Heat is contained in considerable quantities in all bodies when at the common temperature of the atmosphere.

62 Great degree of cold at Glasgow,

"From the interesting experiments which were made on cold by Mr Wilson, we learn, that at Glasgow, in the winter of the year 1780, the thermometer on the surface of snow sunk 25 degrees below the beginning of Fahrenheit's scale.

63 In Siberia, and at Hudson's bay.

"We are told by Dr Pallas, that in the deserts of Siberia, during a very intense frost, the mercury was found congealed in thermometers exposed to the atmosphere, and a quantity of that fluid in an open bowl placed in a similar situation, at the same time became solid. The decisive experiments of Mr Hutchins at Hudson's Bay prove, that the freezing point of mercury is very nearly 40° below the *zero* (or 0°) of Fahrenheit. From which it follows, that at the time of Dr Pallas's observation, the atmosphere in Siberia must have been cooled to minus 40. By a paper lately transmitted to the Royal Society we are informed, that the spirit-of-wine thermometer in the open air at Hudson's Bay fell to — 42 in the winter of 1785; and from the same communication we learn, that by a mixture of snow and vitriolic acid, the heat was so much diminished, that the spirit of wine sunk to — 80, which is 112 below the freezing point of water.

64 Quantity of heat limited in all bodies.

"Hence it is manifest, that heat is contained in considerable quantities in all bodies when at the common temperature of the atmosphere. It is plain, however, that the quantity inherent in each individual body is limited. This, I think, must be admitted, whatever be the hypothesis which we adopt concerning the nature of heat; whether we conceive it to be a force or power belonging to bodies, or an elementary principle contained in them. For those who consider heat as an element, will not suppose that an unlimited quantity of it can be contained in a finite body; and if heat be considered as a force or power, the supposition that finite bodies are actuated by forces or powers which are infinite is equally inadmissible.

65 Bodies universally expanded by heat.

"To place this in another light, we know that bodies are universally expanded by heat, excepting in a very few instances, which do not afford a just objection to the general fact; because, in those instances, by the action of heat a fluid is extricated that previously separated the particles from each other. Since, therefore, heat is found to expand bodies in the temperatures which fall within the reach of our observation, we may conclude that the same thing takes place in all temperatures."

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66 Expansion of mercury, &c. proportionable to the degrees of heat.

Our author, by a set of very accurate and laborious experiments, determines that the expansions in mercury and some other fluids are proportionable to the quantities of heat applied; "from which (says he) it is manifest, that the quantities of heat in bodies are limited, because an infinite heat would produce an infinite expansion.

"It is manifest, that the number of degrees of sensible heat, as measured by the thermometer, and estimated from the beginning of the scale, must be the same in all bodies which have a common temperature; for by the first general fact it is proved, that heat has a constant tendency to diffuse itself uniformly over bodies till their temperatures become equal. From which it may be inferred, that if a quantity of heat were added to bodies absolutely cold, the same uniform diffusion would take place; and that if a thermometer, altogether deprived of its heat, were applied to such bodies, it would be equally expanded by them, the whole of the sensible heat which they had acquired being indicated by that expansion.

67 Homogeneous bodies of the same temperature, contain quantities of heat proportionable to those of their matter.

"III. If the parts of the same homogeneous substance have a common temperature, the quantity of absolute heat will be proportional to the bulk or quantity of matter. Thus the quantity of absolute heat in two pounds of water is double that which is contained in one pound when at the same temperature.

"IV. The dilatations and contractions of the fluid in the mercurial thermometer are nearly proportional to the quantities of absolute heat which are communicated to the same homogeneous bodies, or separated from them, as long as they retain the same form. Thus the quantity of heat required to raise a body four degrees in temperature by the mercurial thermometer, is nearly double that which is required to raise it two degrees, four times that required to raise it one degree, and so in proportion."

Thus we find, that Dr Black, Dr Irvine, Dr Crawford, and Dr Berkenhout, agree in speaking of fire or heat as a fluid substance distinct from all other bodies.

68 Mr Kirwan's opinion concerning fire.

Mr Kirwan, in his Treatise of Phlogiston, agrees in the same opinion. "Some (says he) have thought, that I should have included the matter of heat, or elementary fire, in the definition of inflammable air; but as fire is contained in all corporeal substances, to mention it is perfectly needless, except where bodies differ from each other in the quantity of it they contain."

69 Mr Cavendish's opinion that it is not a distinct substance.

On the other hand, Mr Cavendish, Phil. Trans. lxxiv. p. 141. tells us, that "he thinks it more likely that there is no such thing as elementary heat:" but, as he gives no reason for this opinion, it seems probable that the greater part of philosophers either positively believe that heat is an elementary fluid distinct from all others, or find themselves obliged to adopt a language which necessarily implies it.

70 Difficulty in defining the phrase *quantity of heat.*

The only difficulty which now remains therefore is, to affix a proper idea to the phrase *quantity of heat*, which we find universally made use of, without any thing to determine our opinions concerning it.

71 This phrase cannot be used in the common acceptation of the word with regard to fire.

That we cannot speak of a *quantity* of fire or heat in the same sense as we speak of a quantity of water or any other fluid is evident, because we can take away the quantity of water which any substance contains, but cannot do so with heat. Nay, in many cases we are sure, that a substance very cold to the touch does

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yet contain a very confiderable quantity of heat. The vapour of water, for inftance, may be made much colder than the ufual temperature of the atmofphere without being condenfed, when at the fame time we are certain that it contains a great quantity of heat; and the fame may be faid of water, which, in the act of freezing, throws out a great quantity of heat without becoming colder; and in the act of melting abforbs as much without becoming warmer. It is not therefore by the mere prefence or abfence of this fluid that we can determine the real quantity of this fluid; nor does it appear that the word *quantity* can be at all accurately applied to the element itfelf, becaufe we have no method of meafuring it.

72 Dr Cleghorn's opinion.

Dr Cleghorn, in his inaugural differtation *De Igne* throws fome light on this fubject, by obferving, that "the thermometer fhows only the quantity of heat *going out* of a body, not that which is really contained in it:" and he alfo infifts, that "we can neither affent to the opinion of Dr Boerhaave, who fuppofed that heat was diftributed among bodies in proportion to their bulks; nor to the hypothefis of others, who imagined that they were heated in proportion to their denfities." But in what proportion, then, are they heated; or how are we to meafure the *quantity* which they really contain, feeing the thermometer informs us only of what they part with?

73 The latent heat of bodies cannot be meafured.

As this point is by no means afcertained, we cannot form a direct idea concerning the abfolute quantity of heat contained in any body; and therefore when we fpeak of quantities of this fluid, we muft in fact, if we mean any thing, think of the fenfible quantity flowing out of them; and though we fhould fuppofe the whole of this fenfible heat to be removed, it would ftill be impoffible for us to know how much remained in a latent ftate, and could not be diffipated. This difficulty

74 Dr Cleghorn's hypothefis concerning fire.

will ftill appear the greater, if with Dr Cleghorn and others we fuppofe the fluid of heat to be fubject to the laws of attraction and repulfion. This gentleman fuppofes, that the particles of heat (like the particles of electric fluid according to the Franklinian hypothefis) are repulfive of one another, but attracted by all other fubftances. "If any body (fays he), heated beyond the common temperature of the air, is expofed to it, the heat flows out from it into the atmofphere, and diffufes itfelf equally all around till the air becomes of the fame temperature with itfelf. The fame happens to bodies fufpended *in vacuo*. Hence it is juftly concluded, that there exifts between the particles of heat a repulfive power, by which they mutually recede from each other. Notwithftanding this repulfive power, however, the quantities of heat contained in different fubftances, even of the fame temperature, are found to be altogether different; and from Dr Black's experiments it now appears, that the quantity of heat is fcarce ever the fame in any two different bodies: and hence we may conclude, that terreftrial bodies have a power of attracting heat, and that this power is different in different fubftances.—From thefe principles it evidently follows, that heat is diftributed among bodies directly in proportion to their attracting powers, and

75 Equilibrium of heat defined.

inverfely according to the repulfive power between the particles of heat themfelves. Such is the diftribution of heat among bodies in the neighbourhood of each other; and which is called the *equilibrium of heat*, becaufe the thermometer fhows no difference of temperature among them. For feeing the heat is diftributed according to the attracting power of each, the thermometer having alfo a proper attraction of its own, can fhow no difference in the attracting power of each; for which reafon all bodies in the neighbourhood of each other are foon reduced to the fame temperature."

76 The quantity of heat cannot be determind by this hypothefis.

If we affent to Dr Cleghorn's hypothefis, the quantity of heat contained in any fubftance depends, in the firft place, on the attracting power of that fubftance, which is altogether unknown; and, in the fecond place, on the repulfive powers of the particles of heat themfelves, which are equally unknown. To determine the *quantity*, therefore, muft be impoffible. Neither will the mixture of two different fluids, as in Dr Black's experiments, affift us in the leaft; for though water, heated more than mercury, communicates a greater heat to that fluid than the latter does to water; this only fhows that water more readily parts with fome part of the heat it contains than mercury does, but has not the leaft tendency to difcover the quantity contained in either.

77 Dr Crawford's method of determining the proportional quantities of heat.

Dr Crawford, as we have already feen, calls the *degree*, or, if we may vary the phrafe, the *quantity of power* or *element (fluid*, if we may fubftitute a fynonymous word) exifting or prefent in any body, its *abfolute heat*; and lays down a rule for determining the proportional quantities of heat in different bodies. "It will appear (fays he) from the experiments afterwards recited, that if a pound of water and a pound of diaphoretic antimony have a common temperature, the quantity of abfolute heat contained in the former is nearly four times that contained in the latter."—The manner in which he illuftrates this is as follows.

"If four pounds of diaphoretic antimony at 20 be mixed with one pound of ice at 32, the temperature will be nearly 26: the ice will be cooled fix degrees, and the antimony heated fix. If we reverfe the experiment, the effect will be the fame. That is, if we take fix degrees of heat from four pounds of antimony, and add it to a pound of ice, the latter will be heated fix degrees. The fame quantity of heat, therefore, which raifes a pound of ice fix degrees, will raife four pounds of antimony fix degrees.

"If this experiment be made at different temperatures, we fhall have a fimilar refult. If, for example, the antimony at 15, or at any given degree below the freezing point, be mixed with the ice at 32, the heat of the mixture will be the arithmetical mean between that of the warmer and colder fubftance. And fince the capacities of bodies are permanent as long as they retain the fame form, we infer, that the refult would be the fame if the antimony were deprived of all its heat, and were mixed with the ice at 32. But it is evident, that in this cafe the ice would communicate to the antimony the half of its abfolute heat. For if 200 below froft be conceived to be the point of total privation, the antimony will be wholly deprived of its heat when cooled to 200 degrees below 32, and the heat contained in the ice when at 32 will be 200 degrees. If we now fuppofe them to be mixed together, the temperature of the mixture will be half the excefs of the hotter above the colder, or the ice will

be

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be cooled 100 degrees and the antimony heated 100. The one half of the heat, therefore, which was contained in the ice previous to the mixture will be communicated to the antimony; from which it is manifest, that after the mixture the ice and antimony must contain equal quantities of absolute heat.

"To place this in another light, it has been proved, that the same quantity of heat which raises a pound of ice six degrees will raise four pound of antimony six degrees. And as the capacities of bodies, while they retain the same form, are not altered by a change of temperature; it follows, that the same quantity of heat which raises the ice 200 degrees, or any given number of degrees, will raise the antimony an equal number of degrees.

"A pound of ice, therefore, and four pounds of antimony, when at the same temperature, contain equal quantities of absolute heat. But it appears from the third general fact (n° 67.), that four pounds of antimony contain four times as much absolute heat as one pound of antimony; and hence the quantity of absolute heat in a pound of ice is to that in a pound of antimony as four to one."

78 His method insufficient.

From this quotation it is evident, that, notwithstanding all the distinctions which Dr Crawford has laid down betwixt absolute heat and temperature, it is only the *quantity* of the latter that can be measured; and all that we can say concerning the matter is, that when certain bodies are mixed together, some of them part with a greater quantity of heat than others; but how much they *contain* must remain for ever unknown, unless we can fall on some method of measuring the quantity of heat as we do that of any other fluid.

79 Nicholson's account of the theories of heat.

Mr Nicholson, who has collected the principal opinions on the subject of heat, seems undetermined whether to believe the doctrine of Boyle or of Boerhave on the subject. "There are two opinions (says he) concerning heat. According to one opinion, heat consists in a vibratory motion of the parts of bodies among each other, whose greater or less intensity occasions the increase or diminution of temperature. According to the other opinion, heat is a subtile fluid that easily pervades the pores of all bodies, causing them to expand by means of its elasticity or otherwise. Each of these opinions is attended with its peculiar difficulties. The phenomena of heat may be accounted for by either of them, provided certain suppositions be allowed to each respectively; but the want of proof of the truth of such suppositions renders it very difficult, if not impossible, to decide as yet whether heat consists merely in motion or in some peculiar matter. The word *quantity*, applied to heat, will therefore denote either motion or matter, according to the opinion made use of, and may be used indefinitely without determining which.

80 Advantages of the doctrine that heat is caused by vibration,

"The chief advantage which the opinion that heat is caused by mere vibration possesses, is its great simplicity. It is highly probable, that all heated bodies have an intestine motion, or vibration of their parts; and it is certain that percussion, friction, and other methods of agitating the minute parts of bodies, will likewise increase their temperature. Why, then, it is demanded, should we multiply causes, by supposing the existence of an unknown fluid, when the mere vibration of parts which is known to obtain may be applied to explain the phenomena?"

81 Answer to Mr Nicholson's argument.

To this the reply is obvious, that the vibration of parts is an *effect*; for matter will not begin to move of itself: and if it is an effect, we must suppose a cause for it; which, though we should not call it a fluid, would be equally unknown and inexplicable with that whose existence is asserted by those who maintain that fire is a fluid *per se*. Dr Cleghorn, however, in the dissertation already quoted, asserts, that "heat is occasioned by a certain fluid, and not by motion alone, as some eminent writers have imagined: because, 1. Those who have adopted the hypothesis of motion could never even prove the existence of that motion for which they contended; and though it should be granted, the phenomena could not be explained by it. 2. If heat depended on motion, it would instantaneously pass through an elastic body; but we see that heat passes through bodies slowly like a fluid. 3. If heat depended on vibration, it ought to be communicated from a given vibration in proportion to the quantity of matter; which is found not to hold true in fact. On the other hand, there are numberless arguments in favour of the opinion that heat proceeds from elementary fire. 1. Mr Locke hath observed, that when we perceive a number of qualities always existing together, we may gather from thence that there really is some substance which produces these qualities. 2. The hypothesis of elementary fire is simple and agreeable to the phenomena. 3. From some experiments made by Sir Isaac Newton, it appears, that bodies acquire heat and cold *in vacuo*, until they become of the same temperature with the atmosphere; so that heat exists in the absence of all other matter, and is therefore a substance by itself."

82 Dr Cleghorn's proof that heat is occasioned by a fluid.

83 Difficulties concerning the nature and properties of Fire.

But though these and other arguments seem clearly to establish the point that fire or heat is a distinct fluid, we are still involved in very great difficulties concerning its nature and properties. If it be supposed a fluid, it is impossible to assign any limits to its extent; and we must of necessity likewise suppose that it pervades the whole creation, and consequently constitutes an absolute plenum, contrary to a fundamental principle of the received system of natural philosophy. But if this is the case, it is vain to talk of its being absorbed, accumulated, collected, or attracted by different bodies, since it is already present in all points of space; and we can conceive of terrestrial bodies no otherwise than as sponges thrown into the ocean, each of which will be as full of fluid as it can hold. The different capacities will then be similar to the differences between bits of wood, sponge, porous stones, &c. for containing water; all of which depend entirely on the structure of the bodies themselves, and which, unless we could separate the water by pressure, or by evaporation, would be for ever unknown. Supposing it were impossible to collect this water in the manner we speak of, we could only judge of the quantity they contained by the degree to which they swelled by being immersed in it. It is easy to see, however, that such a method of judging would be very inadequate to the purpose, as substances might contain internal cavities or pores in which water could lodge without augmenting the external bulk. This would suggest another method of judging of the quantity, namely, the specific gravity;

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vity; and we might reaſonably ſuppoſe, that ſubſtances of the greateſt ſpecific gravity would contain the ſmalleſt quantity of water, though ſtill we could by no means determine what quantity they did contain, unleſs we could lay hold of the element itſelf.

This ſeems to be very much the caſe with elementary fire, if we ſuppoſe it to be a fluid *per ſe*. We judge of its preſence by the degree of expanſion which one heated body communicates to another: but this is only ſimilar to the calculation of the quantity of moiſture a ſponge or any other body contains, by what it communicates to wood when it comes into contact with it; which never could be ſuppoſed to carry the leaſt pretenſions to accuracy, though we ſhould aſcertain it with all imaginable exactneſs. It is likewiſe probable, that the moſt denſe bodies contain the ſmalleſt quantity of fire, as they generally communicate leſs when heated to an equal temperature than thoſe which are more rare, though we are far from having any perfect knowledge in this reſpect.

84 Difficulty ariſing from the ſuppoſition that heat diffuſes itſelf equally.

But the greateſt difficulty of all will be, on the ſuppoſition that heat is a fluid, and an omnipreſent one (which it muſt be, or there would be ſome places where bodies could not be heated), to anſwer the queſtion, Why are not all bodies of an equal temperature, excepting only the differences ariſing from their ſpecific denſities, which render ſome capable of containing a greater quantity than others?—The difficulty will not be leſſened, though the omnipreſence of the fluid ſhould be given up, if we ſuppoſe, as is generally done, that heat has a tendency to diffuſe itſelf equably every way. If it has this tendency, what hinders it from doing ſo? Why doth not the heat from the burning regions of the torrid zone diffuſe itſelf equally all over the globe, and reduce the earth to one common temperature? This indeed might require time; but the experience of all ages has ſhown that there is not the leaſt advance towards an equality of temperature. The middle regions of the earth continue as hot, and the polar ones as cold, as we have any reaſon to believe they were at the creation of the world, or as we have any reaſon to believe they will be while the world remains. This indeed is one of the many inſtances of the impropriety of eſtabliſhing general laws from the trifling experiments we are capable of making, and which hold good only on the narrow ſcales on which we can make them, but are utterly inſufficient to ſolve the phenomena of the great ſyſtem of nature, and which can be ſolved only by obſerving other phenomena of the ſame ſyſtem undiſturbed by any manoeuvres of our own.

85 Another from the ſeeming diſappearance of the heat.

Again, ſuppoſing the objection already made could be got over, and ſatisfactory reaſons ſhould be given why an equilibrium of temperature in the earth and its atmoſphere ſhould never be obtained, it will by no means be eaſy to tell what becomes of the heat which is communicated to the earth at certain times of the year. This difficulty, or ſomething ſimilar, Dr Crawford ſeems to have had in view when treating of the effects of the evolution and abſorption of heat. Thus, ſays he, "the Deity has guarded againſt ſudden viciſſitudes of heat and cold upon the ſurface of the earth.

86 Dr Crawford's ſolution.

"For if heat were not evolved by the proceſs of congelation, all the waters which were expoſed to the influence of the external air, when its temperature was reduced below 32°, would ſpeedily become ſolid; and, at the moment of congelation, the progreſs of cooling would be as rapid at it was before the air had arrived at its freezing point.

"This is manifeſt from what was formerly obſerved reſpecting the congelation of different fluids. It was ſhown, that if the velocities of the ſeparation of heat were equal, the times of the congelation would be in proportion to the quantities of heat which the fluids gave off from an internal ſource in the freezing proceſs. Whence it follows, that if no heat were evolved, the congelation ſhould be inſtantaneous.

"In the preſent ſtate of things, as ſoon as the atmoſphere is cooled below 32°, the waters begin to freeze, and at the ſame time to evolve heat; in conſequence of which, whatever may be the degree of cold in the external air, the freezing maſs remains at 32°, until the whole is congealed; and as the quantity of heat extricated in the freezing of water is conſiderable, the progreſs of congelation in large maſſes is very ſlow.—That the abſorption and extrication of heat in the melting and freezing of bodies has a tendency to retard the progreſs of theſe proceſſes, is remarked by Mr Wilkie in his eſſay on latent Heat.—The ſame doctrine is likewiſe taught by Dr Black in his lectures.

"In the northern and ſouthern regions, therefore, upon the approach of winter, a quantity of elementary fire is extricated from the waters, proportional to the degree of cold that prevails in the atmoſphere. Thus the ſeverity of the froſt is mitigated, and its progreſs retarded; and it would ſeem that, during this retardation of the cooling proceſs, the various tribes of animals and vegetables which inhabit the circumpolar regions gradually acquire power of reſiſting its influence.

87 Severity of the cold in the northern regions mitigated by the production of ice.

"On the contrary, if, in the melting of ice, a quantity of heat were not abſorbed, and rendered inſenſible, that ſubſtance, when it was expoſed to a medium warmer than 32°, would ſpeedily become fluid, and the proceſs of heating would be as rapid as if no alteration in its form had taken place. If things were thus conſtituted, the vaſt maſſes of ice and ſnow which are collected in the frigid zones would, upon the approach of ſummer, ſuddenly diſſolve, and great inundations would annually overflow the regions near to the poles.

88 Inundations prevented by the ſlowneſs with which congealed water melts.

"But by the operation of the law of the abſorption of heat, when the ice and ſnow upon the return of ſpring have arrived at 32°, they begin to melt, and at the ſame time to imbibe heat: during this proceſs, a large quantity of elementary fire becomes inſenſible; in conſequence of which the earth is ſlowly heated, and thoſe gradual changes are produced which are eſſential to the preſervation of the animal and vegetable kingdoms.

"We may remark, in the laſt place, that this law not only reſiſts ſudden changes of temperature, but that it likewiſe contributes to a more equal diſtribution of the principle of heat throughout the various parts of the earth, in different ſeaſons and climates. Thus the diurnal heats are moderated by the evaporation of the waters on the earth's ſurface, a portion of the fire derived from the ſun being abſorbed and extinguiſhed by the vapours at the moment of their aſcent. On the approach of night the vapours are again condenſed, and falling in the form of dew, communicate

89 Equal diſtribution of heat promoted by its abſorption and evolution.

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to the air and to the earth the fire which they had imbibed during the day.

"It was before shown, that, in the regions near to the poles, when the vernal and summer heats prevail, provision is made for tempering the severity of the winter cold, a quantity of elementary fire, upon the dissolution of the ice and snow, being absorbed by the waters, and deposited, as it were, in a great magazine for the purpose of mitigating the intensity of the cold when the frost returns.

90 Heat of the torrid zone thus mitigated.

"From the experiments of Hales, Halley, and Watson, it appears, that vast quantities of water are continually converted into vapour by the action of the solar rays upon the portion of the earth's surface which is exposed to the light; and by the celebrated discovery of Dr Black, it is proved, that, in the process of evaporation, much elementary fire is absorbed. It is manifest, that this cause will have a powerful influence in mitigating the intensity of the heat in the torrid zone, and in promoting a more equal diffusion of it through the earth. For a considerable portion of the heat, which is excited by the action of the solar rays upon the earth's surface within the tropics, is absorbed by the aqueous vapours, which being collected in the form of clouds, are spread like a canopy over the horizon, to defend the subjacent regions from the direct rays of the sun. A great quantity of elementary fire is thus rendered insensible in the torrid zone, and is carried by the dispersion of the vapours to the north and to the south, where it is gradually communicated to the earth when the vapours are condensed."

91 This solution totally insufficient to remove the difficulty.

That all this takes place, as the Doctor has advanced, cannot be denied; but, by allowing it, the difficulty is not removed in the smallest degree, as will appear from a due consideration of the phenomena which he himself has mentioned. He owns that the sun communicates fire to the earth: the question is, What becomes of it, seeing the emission is continual? In summer, the air, the earth, and the water, are heated to a certain degree. On the sun's declining southward, the air first loses its heat. Whither does it go? It does not ascend into the higher regions of the atmosphere, for these are constantly found colder than the parts below. It does not descend to the earth and water; for these give out the quantity they had absorbed, as Dr Crawford observes. Neither does it go laterally to the southern regions; for they are constantly very hot, and ought to impart their heat to those farther north, instead of receiving any from them. How comes it then, that the atmosphere seems perpetually to receive heat without ever being satiated? or if the heat cannot be found going off either upwards, downwards, or sideways, how are we to account for its disappearance?

92 Heat most probably the action of an omnipresent fluid.

This question seems to be altogether unanswerable on the supposition that heat is occasioned by the mere presence of a fluid; but if we suppose it to be only a particular mode of action of an omnipresent fluid, the whole difficulty vanishes at once.—On this supposition indeed the question will naturally arise, Whence does this motion proceed, or by what is its action in general

93 Fire seems destitute of gravity and vis inertiae.

determined? Dr Berkenhout, in enumerating the properties of matter, exempts fire from two of those usually ascribed to other material substances, viz gravitation and the *vis intertiae*. "According to the philosophers (says he), matter cannot move without being either impelled or attracted. I doubt much whether this be true of fire, and whether, when uncombined, motion be not one of its essential properties.—Gravitation seems also to be no property of fire, which moves with equal facility in all directions, and may be accumulated in hard bodies to any degree without increasing their weight. Fire, being the cause of volatility, seems rather to be in constant counteraction to gravity."

But however essential we may suppose the motion of fire to be to it, there cannot be any self-existent mobility in its parts, otherwise it would soon be diffused equally throughout the universe, and the temperature of the whole reduced to an equilibrium. According to the present constitution of nature, we see that the distribution of heat is principally owing to the sun; and what we call its *quantity*, depends on the position of the sun with regard to terrestrial objects and the length of time they are exposed to his rays. Heat is not produced while the rays have a direct passage; and therefore fluids through which they pass easily, as air, are not heated by the rays of the sun. But when the rays are impeded in their course, and reflected in considerable quantity, a degree of heat takes place, which is always greater or less in proportion to the intensity of the rays.—In the reflecting substance, the heat will be comparatively greater in proportion to the quantity of rays which are absorbed or stopped in their course by it: but in any substance interposed betwixt the sun and the reflecting body, the heat is proportional to the quantity of rays reflected.—Now it is plain, that when the particles of light fall upon any opaque substance, and enter its pores, which by their extreme subtilty they are well calculated to do, they must make an attempt to pass directly through it in their natural course; but as this cannot be done, they will push laterally, and in all directions, in consequence of being perpetually urged by the impulse of the light coming from the sun: and thus an action will be propagated in all directions as radii from a centre towards a circumference, which when it takes place in that subtile fluid always produces what we call *heat*.

94 Distribution of heat owing to the sun.

95 How heat is produced by the sun's rays.

96 Proofs of the identity of fire, light, and electricity.

In completing the system of nature, we perceive three kinds of fluids of extreme subtilty, and very much resembling one another, viz. fire, light, and electricity. That it should be agreeable to vulgar conceptions to suppose these all to be ultimately the same, is not surprising; and on examining the evidence of their identity, it will certainly be found exceedingly strong. They all agree in the property of exciting the sensation of heat in certain circumstances, and in not doing so in others. Fire, we know, in the common acceptation of the word, always does so; but when it assumes the latent and invisible state, as in the formation of vapour, it lays aside this seemingly essential property, and the vapour is cold to the touch.—Light, when collected in a focus by a burning glass, i. e. when its rays converge towards a centre, and diverge or attempt to diverge from one, produces heat also: and so does the electric fluid; for it has been found that the aura converging from a very large conductor to the point of a needle, is capable of setting on fire a small cartridge of gunpowder, or a quantity of tinder surrounding it *. There seems also to be a connection betwixt fire

* See *Electricity*.

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fire and electricity in another way; for in proportion as heat is diminiſhed, or the bodies are cooled, electricity ſucceeds in its place. Thus all electric bodies by heat become conductors of electricity, and cannot be excited or made to ſhow any ſigns of containing that fluid; but as ſoon as the heat is removed, their electric property returns. Water is naturally a conducting ſubſtance: by being frozen its conducting power is leſſened, which ſhows an approach to electricity; and, by being cooled down to 20° below 0 of Fahrenheit, the ice actually becomes electric, and will emit ſparks by friction like glaſs*. The atmoſphere is a natural electric: but by a certain degree of heat it loſes this property, and becomes a conductor; nor is there any doubt that its electric properties are increaſed in proportion to the degree of cold imparted to it. In the winter time, therefore, we muſt conſider the frozen ſurface of the earth, the water, and the atmoſphere of the polar regions, as forming one electrical machine of enormous magnitude; for the natural cold of theſe countries is often ſufficient to cool the water to more than 20° below 0, and conſequently to render it an electric. That this is really the caſe, appears from the exceſſively bright aurora borealis and other electric appearances, far exceeding any thing obſerved in this country. In the ſummer time, however, no ſuch appearances are to be ſeen, nor any thing remarkable except an exceſſive heat from the long continuance of the ſun above the horizon. This quantity of heat then being ſucceeded by a proportionable quantity of electricity in winter, it is impoſſible to avoid concluding that the heat in ſummer becomes electric fluid in winter, which, going off through the celeſtial expanſe, returns again to the grand ſource of light and heat from which it originally came; thus making room for the ſucceeding quantities which are to enliven the earth during the following ſummer.

97 Connection between fire or heat and electricity.

* See *Electricity*.

98 Exceſſive electricity of the polar regions in winter.

99 Heat in ſummer becomes electric fluid in winter.

Thus the diſappearance of heat in winter, and of electricity in ſummer, in theſe countries, will be very naturally and eaſily accounted for. It is true, that the phenomena of thunder and lightning ſhow the exiſtence of this fluid in vaſt quantities during the ſummer ſeaſon: but theſe phenomena are only partial, and though formidable to us, are trifling in compariſon with the vaſt quantities of electric matter diſcharged by the continual flaſhing of the aurora borealis, not to mention the fire-balls and meteors called *falling ſtars*, which are very often to be ſeen in the northern countries. In the ſummer-time, the air which is an electric, heated by the rays of the ſun, is excited or made to part with the fluid to the vapours contained in it; and it is the unequal or oppoſite electricity of the clouds to one another, or to the earth, which produces the lightning. But in winter, when the air, earth, and vapours, all become electric, they cannot diſcharge ſparks from one to another as before; but the whole, as one connected and vaſt electrified apparatus, diſcharges the matter almoſt in a continued ſtream for many months.

100 Why thunder and lightning take place in ſummer and not in winter.

101 Heat, light, cold, and electricity, the effects of one univerſal fluid

From a conſideration of theſe and other phenomena of nature, as well as of the beſt experiments which have hitherto been made, we muſt conſider fire in the abſtract as an omnipreſent fluid, of ſuch ſubtilty as to pervade all terreſtrial ſubſtances. When by any means it is made to diverge every way as from a centre, there it operates as heat; expands, rarefies, or burns, according to the intenſity of its action. Proceeding in ſtraight and parallel lines, or ſuch as diverge but little, it acts as light, and ſhows none of that power diſcoverable in the former caſe, though this is eaſily diſcoverable by making it converge into a focus. In a quieſcent ſtate, or where the motion is but little, it preſſes on the ſurfaces of bodies, contracts and diminiſhes them every way in bulk, forces out the expanding fluid within their pores, and then acts as cold. In this caſe alſo, being obliged to ſuſtain the vehement action of that part of the fluid which is in motion, it flies with violence to every place where the preſſure is leſſened, and produces all the phenomena of Electricity.

Nature of Heat.

§ 1. *Of the Nature of Heat.*

102 Particular ſolution of the phenomena of heat.

The manner in which the phenomena of heat may be ſolved, and its nature underſtood, will appear from the following propoſitions.

1. It is in all caſes obſerved, that when light proceeds in conſiderable quantity from a point, diverging as the radii of a circle from its centre, there a conſiderable degree of heat is found to exiſt, if an opaque body, having no great reflective power, is brought near that point.

2. This action of the light, therefore, may be accounted the ultimate cauſe of heat, without having recourſe to any farther ſuppoſitions; becauſe nothing elſe beſides this action is evident to our ſenſes.

3. If the point from which the rays are emitted is placed in a tranſparent medium, ſuch as air or water, that medium, without the preſence of an opaque body, will not be heated.

4. Another cauſe of heat, therefore, is the reſiſtance of the parts of that body on which the light falls, to the action mentioned in Prop. 1. Where this reſiſtance is weak, as in the caſes juſt mentioned, the heat is either nothing, or very little.

5. If a body capable of reflecting light very copiouſly is brought near the lucid point, it will not be heated*.

* See the article *Burning-Glaſs*.

6. A penetration of the light, therefore, into the ſubſtance of the body, and likewiſe a conſiderable degree of reſiſtance on the part of that body to the action of the light, are the requiſites to produce heat.

7. Thoſe bodies ought to conceive the greateſt degrees of heat into whoſe ſubſtance the light can beſt penetrate, *i. e.* which have the leaſt reflective power, and which moſt ſtrongly reſiſt its action; which is evidently the caſe with black and ſolid ſubſtances.

8. By heat all bodies are expanded in their dimenſions every way, and that in proportion to their bulk and the quantity of heat communicated to them.

9. This expanſion takes place not only by an addition of *ſenſible* heat, but likewiſe of that which is *latent*. Of this laſt we have a remarkable inſtance in the caſe of ſnow mixed with ſpirit of nitre. The ſpirit of nitre contains a certain quantity of latent heat, which cannot be ſeparated from it without effecting a change on the ſpirit itſelf; ſo that, if deprived of this heat, it would no longer be ſpirit of nitre.—Beſides this, it contains a quantity of ſenſible heat, of a great part of which it may be deprived, and yet retain its characteriſtic properties as nitrous acid. When it is poured upon ſnow, the latter is immediately melted by the action of the latent heat in the acid. The ſnow cannot

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be melted or converted into water, without imbibing a quantity of latent heat, which it receives immediately from the acid which melts it. But the acid cannot part with the heat without decompofition; to prevent which, its fenfible heat occupies the place of that which has entered the fnow and liquefied it. The mixture then becomes exceedingly cold, and the heat forces into it from all the bodies in the neighbourhood; fo that, by the time it has recovered that quantity of fenfible heat which was loft, or arrived at the temperature of the atmofphere around it, it will contain a confiderably larger quantity of heat than it originally did, and is therefore obferved to be expanded in bulk. Another inftance of this expanfive power of latent heat is in the cafe of fteam, which always occupies a much larger fpace than the fubftance from which it was produced; and this whether its temperature is greater or lefs than the furrounding atmofphere.

10. The difference between latent and fenfible heat, then, as far as we can conceive, is, that the expanfive power of the former is directed only againft the particles of which the body is compofed; but that of the latter is directed alfo againft other bodies. Neither doth there feem to be any difference at all between them farther than in quantity. If water, for inftance, hath but a fmall quantity of heat, its parts are brought near each other, it contracts in bulk, and feels cold. Still, however, fome part of the heat is detained among the aqueous particles, which prevents the fluid from congealing into a folid mafs. But, by a continuation of the contracting power of the cold, the particles of water are at laft brought fo near each other that the internal or *latent* heat is forced out. By this difcharge a quantity of air is alfo produced, the water is congealed, and the ice occupies a greater fpace than the water did; but then it is full of air-bubbles, which are evidently the caufe of its expanfion. The heat then becomes *fenfible*, or, as it were, lies on the outfide of the matter; and confequently is eafily diffipated into the air, or communicated to other bodies. Another way in which the latent heat may be extricated is by a conftant addition of fenfible heat. In this cafe the body is firft raifed into vapour, which for fome time carries off the redundant quantity of heat. But as the quantity of this heat is continually increafed, the texture of the vapour itfelf is at laft totally deftroyed. It becomes too much expanded to contain the heat, which is therefore violently thrown out on all fides into the atmofphere, and the body is faid to burn, or be on fire. See COMBUSTION, FLAME, and IGNITION.

11. Hence it follows, that thofe bodies which have the leaft fhare of latent heat, appear to have the greateft quantity of fenfible heat; but this is only in appearance, for the great quantity they feem to contain is owing really to their inability to contain it. Thus, if we can fuppofe a fubftance capable of tranfmitting heat through it as faft as it received it; if fuch a fubftance was fet over a fire, it would be as hot as the fire itfelf, and yet the moment it was taken off, it would be perfectly cool, on account of its incapacity to detain the heat among the particles of which it was compofed.

12. The heat, therefore, in all bodies confifts in a certain violent action of the elementary fire within them tending from a centre to a circumference, and thus making an effort to feparate the particles of the body from each other, and thereby to change its form or mode of exiftence. When this change is effected, bodies are faid to be diffipated in vapour, calcined, vitrified, or burnt, according to their different natures.

13. Inflammable bodies are fuch as are eafily raifed in vapours; that is, the fire eafily penetrates their parts, and combines with them in fuch quantity, that, becoming exceedingly light, they are carried up by the atmofphere. Every fucceeding addition of heat to the body increafes alfo the quantity of latent heat in the vapour, till at laft, being unable to refift its action, the heat breaks out all at once, the vapour is converted into flame, and is totally decompofed. See the article FLAME, and Prop. 10.

14. Uninflammable bodies are thofe which have their parts more firmly connected, or otherwife difpofed in fuch a manner, that the particles of heat cannot eafily combine with them or raife them into vapour.

15. Heat therefore being only a certain mode of the action of elementary fire, it follows, that the capacity of a body for containing it, is only a certain conftitution of the body itfelf, or a difpofition of its parts, which can allow the elementary fire contained in it to exert its expanfive power upon them without being diffipated on other bodies. Thofe fubftances which allow the expanfive power of the fire to operate on their own particles are faid to contain a great deal of heat; but thofe which throw it away from themfelves upon other bodies, though they feel very hot, yet philofophically fpeaking they contain very little heat.

16. What is called the *quantity* of heat contained in any fubftance, if we would fpeak with the ftricteft propriety, is only the apparent force of its action, either upon the parts of the body itfelf, or upon other bodies in its neighbourhood. The expanfive force of the elementary fire contained in any body upon the parts of that body, is the *quantity of latent heat* contained in it; and the expanfive force of the fire exerted upon other bodies which touch or come near it, is the *quantity of fenfible heat* it contains.

17. If what we call *heat* confifts only in a certain action of that fluid called *elementary fire*, namely, its expanfion, or acting from a centre to a circumference, it follows, that if the fame fluid act in a manner directly oppofite to the former, or prefs upon the particles of a body as from a circumference to a centre, it will then produce effects directly oppofite to thofe of heat, i. e. it will then be abfolute *cold*, and produce all the effects already attributed to COLD. See that article.

18. If heat and cold then are only two different modifications of the fame fluid, it follows, that if a hot body and a cold one are fuddenly brought near each other, the heat of the one ought to drive before it a part of the cold contained in the other, *i. e.* the two portions of elementary fire acting in two oppofite ways, ought in fome meafure to operate upon one another as any two different bodies would when driven againft each other. When a hot and a cold body therefore are brought near each other, that part of the cold body fartheft from the hot one ought to become colder than before, and that part of the hot body fartheft from the cold one ought to become hotter than before.

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19. For the ſame reaſon, the greateſt degree of cold in any body ought to be no obſtacle, or at leaſt very little, to its conceiving heat, when put in a proper ſituation. Cold air, cold fuel, &c. ought to become as intenſely heated, and nearly as ſoon, as that which is hotter.

The two laſt propoſitions are of great importance. When the firſt of them is thoroughly eſtabliſhed, it will confirm beyond a doubt, that cold is a *poſitive*, as well as heat; and that each of them has a ſeparate and diſtinct power, of which the action of its antagoniſt is the only proper limit; *i. e.* that heat can only limit the power of cold, and *vice verſa*. A ſtrong confirmation of this propoſition is the experiment related by M. Geoffroy; an account of which is given under the article COLD. Another, but not ſo well authenticated, is related under the article CONGELATION.—De Luc's obſervation alſo, mentioned by Dr Cleghorn, affords a pretty ſtrong proof of it; for if the lower parts of the atmoſphere are cooled by the paſſage of the ſun's rays at ſome diſtance above, and it hath been already ſhown that they do not *attract* the heat from the lower parts, it follows, that they muſt *expel* part of the cold from the upper regions.—The other propoſition, when fully eſtabliſhed, will prove, that heat and cold are really convertible into one another; which indeed ſeems not improbable, as we ſee that fires will burn with the greateſt fierceneſs during the time of intenſe froſts, when the coldeſt air is admitted to them; and even in thoſe diſmal regions of Siberia, when the intenſe cold of the atmoſphere is ſufficient to congeal quickſilver, it cannot be doubted that fires will burn as well as in this country; which could not happen if heat was a fluid *per ſe*, and capable of being carried off, or abſolutely diminiſhed in quantity, either in any part of the atmoſphere itſelf, or in ſuch terreſtrial bodies as are uſed for fuel.

§ 2. *Of the general Effects of Heat.*

HAVING ſaid thus much concerning the nature of heat in general, we come now to a particular explanation of its ſeveral effects, which indeed conſtitute the whole of the active part of chemiſtry.—Theſe are,

I. *Expanſion*, or increaſe of bulk in every direction. This is a neceſſary conſequence of the endeavour which the fluid makes to eſcape in all directions, when made to converge into a focus. The degree of expanſion is unequal in different bodies, but in the ſame body is always proportionable to the degree of heat

103 Inſtruments for meaſuring the expanſions of bodies.

applied. There are two different inſtruments in uſe for aſcertaining the degrees of expanſion; and as we have already ſhown, that the degree of heat can only be known by the expanſion, theſe effects of heat upon the inſtrument are uſually taken for the degrees of heat themſelves. Theſe inſtruments are called the THERMOMETER and PYROMETER. The former is compoſed of a glaſs tube, with a globe or rather oval tube at one end, and exactly cloſed at the other: it is moſt uſually filled with mercury or ſpirit of wine; but mercury is generally preferred on account of its expanſions being more equable than thoſe of any other fluid. It has the diſadvantage, however, of being ſubject to congelation; which is not the caſe with ſpirit of wine, when very highly rectified. Spirit-of-wine thermometers, therefore ought not to be entirely diſuſed, but ſeem rather a neceſſary part of the chemical apparatus, as well as thoſe made of mercury.

104 Wedgewood's improvement of the thermometer.

As no thermometer made with any fluid can meaſure either the degrees of heat about the point at which it boils, or the degree of cold below which it congeals, inſtruments have been contrived by which the expanſion of ſolid bodies, though much leſs than what is occaſioned by an equal degree of heat in a fluid, may become viſible. Theſe were uſually called *Pyrometers*; but Mr Wedgewood has lately contrived a method of connecting the two together, in which the higheſt degree of heat, exceeding even that of a glaſs-houſe furnace, may be meaſured as accurately as the more moderate degrees by the common mercurial thermometer. See THERMOMETER.

105 Inſtances of bodies expanding by cold.

Expanſion in ſome caſes does not appear to be the effect of heat, of which we have two remarkable inſtances, viz. of iron, which always expands in cooling after it has been melted; and of water, which expands with prodigious force in the act of freezing. The power with which iron expands in the act of paſſing from a fluid to a ſolid ſtate, has never been meaſured, nor indeed does it ſeem eaſy to do ſo; but that of freezing water has been accurately computed. 106

106 Prodigious force exerted by water in freezing.

This was done by the Florentine Academicians, who having filled an hollow braſs ball of an inch diameter, with water, expoſed it to a mixture of ſnow and ſalt, in order to congeal the water, and try whether its force was ſufficient to burſt the ball or not. The ball, being made very ſtrong, reſiſted the expanding force of the water twice, even though a conſiderable part of its thickneſs had been pared off when it was perceived too ſtrong at firſt. At the third time it burſt; and by a calculation founded on the thickneſs of the globe and the tenacity of the metal, it was found that the expanſive power of a ſpherule of water only one inch in diameter, was ſufficient to overcome a reſiſtance of more than 27,000 pounds, or 13 tons and an half. 107

107 Uſed as an argument for the exiſtence of cold as a poſitive ſubſtance.

A power of expanſion ſo prodigious, little leſs than double that of the moſt powerful ſteam-engines, and exerted in ſo ſmall a body, ſeemingly by the force of cold, was thought to be a very powerful argument in favour of thoſe who ſuppoſe cold to be a poſitive ſubſtance as well as heat; and indeed contributed not a little to embarraſs the oppoſite party. Dr Black's 108

108 Explained by Dr Black's theory of latent heat.

diſcovery of latent heat, however, has now afforded a very eaſy and natural explication of this phenomenon. He has ſhown, that, in the act of congelation, water is not cooled more than it was before, but rather grows warmer: that as much heat is diſcharged, and paſſes from a latent to a ſenſible ſtate, as, had it been applied to water in its fluid ſtate, would have heated it to 135°. In this proceſs the expanſion is 109

109 The expanſion produced by the extrication of air-bubbles.

occaſioned by a great number of minute bubbles ſuddenly produced. Theſe were formerly ſuppoſed to be formed of *cold* in the abſtract; and to be ſo ſubtile, that, inſinuating themſelves into the ſubſtances of the fluid, they augmented its bulk, at the ſame time that, by impeding the motion of its particles upon each other, they changed it from a fluid to a ſolid. Dr Black, however, has demonſtrated, that theſe are only air extricated during the congelation; and to the extrication of this air he very juſtly attributes the prodigious expanſive force exerted by freezing water. The

only

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only queftion, therefore, which now remains is, By what means this air comes to be extricated, and to take up more room than it naturally does in the fluid? To

110 This air extricated by part of the heat contained in the water.

this we can fcarce give any other anfwer, than that part of the heat which is difcharged from the freezing water combines with the air in its unelaftic ftate, and, by reftoring its elafticity, gives it that extraordinary force, as we fee alfo in the cafe of air fuddenly extricated in the explofion of gunpowder. Thus expanfion, even in the cafe of freezing, is properly an effect of heat; and muft therefore be confidered as a phenomenon uniformly and certainly attending the action of heat, and in all cafes to be afcribed to it.

111 Capacity of a body for containing heat, the fame with the action of heat upon that body.

The only way in which the element or fluid of fire can be fuppofed to act, and the way in which we can have a rational idea of its being able to produce both heat and cold according to the diverfity of its action, has been already explained fo fully, that it is needlefs at prefent to enter into any further difcuffion of the fubject. It will eafily appear, that the *capacity* for containing heat is nothing different from the action of heat upon that body in expanding, and at laft altering its form in fuch a manner, as either to be able to infinuate itfelf among the particles in much greater quantity than before, ftill retaining its internal action, though the external one becomes imperceptible; or fcattering them in fuch a manner, that it breaks forth in great quantity in its peculiar appearances of fire and light; in the former cafe producing vapour or

112 Impoffibility of determining the quantity of heat any body contains.

fmoke, and in the latter flame, as fhall afterwards be more fully explained. It muft likewife appear, that to determine the quantity of heat in any body is altogether impoffible: and with regard to the loweft degree of heat, or total expulfion of that fluid, fo far from being able to determine what it is, the probability muft be, that nature does not admit of any fuch thing; for if heat confifts in the expanfive action of a certain fluid, and cold in its oppofite or contractile action, there is very little reafon to fuppofe that the conftitution of nature will allow any one of thefe actions intirely to ceafe, as it does not appear by what means it could again be renewed. Cold, as we have already feen, always tends to produce electricity; and the connexion betwixt that and fire is fo ftrong, that we cannot fuppofe the former to be carried to any great extreme without producing the latter. Whatever we may therefore fuppofe concerning the capacities of different bodies for containing heat, or concerning the point of total privation of heat, muft be altogether void of foundation. A rule, however, has been given by Mr Kirwan for finding the point of total privation, which, together with its demonftration, we fhall fubjoin; and as it is neceffary for the better underftanding of this, to call to remembrance what has been faid concerning the difference between the temperatures and fpecific heats of bodies, we fhall infert an epitome of the doctrine from Mr Nicholfon.

113 Mr Nicholfon's account of the capacities of bodies for containing heat, &c.

"If two equal bodies of different kinds and temperatures be brought into contact, the common temperature, will feldom, if ever, be the mean betwixt the two original temperatures; that is to fay, the furplus of heat in the hotter body will be unequally divided between them, and the proportions of this furplus retained by each body will exprefs their refpective difpofitions, affinities, or capacities for heat.—If, therefore, a given fubftance, as for example fluid water, be taken as the ftandard of comparifon, and its capacity for heat be called one, or unity, the refpective capacities of their bodies may be determined by experiment, and expreffed in numbers in the fame manner as fpecific gravities ufually are. And becaufe it is eftablifhed as well from reafon as experiment, that the fame capacity for heat obtains in all temperatures of a given body, fo long as its ftate of folidity, fluidity, or vapour is not changed, it will follow, that the whole quantities of heat in equal bodies of a given temperature will be as thofe capacities. And as the refpective quantities of matter, in bodies of equal volume, give the proportions of their fpecific gravities, fo the refpective quantities of heat in bodies of equal weight and temperature give the proportions of their fpecific heats.

"A greater capacity for heat, or greater fpecific heat, in a given body, anfwers the fame purpofe with refpect to temperature as an increafe of the mafs; or the quantity of heat required to be added or fubducted, in order to bring a body to a given temperature, will be as its capacity or fpecific heat.

"The capacities not only differ in various bodies, but alfo in the fame body, according as it is either in a folid, fluid, or vaporous ftate. All the experiments hitherto made confpire to fhow, that the capacity, and confequently the fpecific heat, is greateft in the vaporous, lefs in the fluid, and leaft in the folid ftate.

"The quantity of heat that conftitutes the difference between the feveral ftates, may be found in degrees of the thermometer. Thus if equal quantities of water at 162° and ice at 32° of temperature be mixed, the ice melts, and the common temperature becomes 32°; or otherwife, if equal quantities of frozen or fluid water, both at 32°, be placed in a like fituation to acquire heat from a fire, the water will become heated to 162°, while the ice melts without acquiring any increafe of temperature. In either cafe the ice acquires 130° of heat, which produces no other effect than rendering it fluid. Fluid water, therefore, contains not only as much more heat than ice, as is indicated by the thermometer, but alfo 130°, that is in fome manner or other employed in giving it fluidity. And as fluid water cannot become ice without parting with 130° of heat befides what it had above 32° in its temperature; fo alfo fteam cannot become condenfed into water without imparting much more heat to the matters it is cooled by, than water at the fame temperature would have done.

"The heat employed in maintaining the fluid or vaporous form of a body, has been called latent heat, becaufe it does not affect the thermometer.

114 Mr Kirwan's theorem for finding the point of total privation of heat.

"From the confideration of the fpecific heats of the fame body in the two ftates of fluidity and folidity, and the difference between thofe fpecific heats, is deduced a method of finding the number of degrees which denote the temperature of any body immediately after congelation, reckoned from the natural zero, or abfolute privation of heat. The rule is; multiply the degrees of heat required to reduce any folid to a fluid ftate, by the number expreffing the fpecific heat of the fluid: divide this product by the difference between the numbers expreffing the fpecific heat of the body in each ftate: the quotient will be the number

of

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of degrees of temperature, reckoned from an absolute privation of heat.

"This theorem is Mr Kirwan's, and may be proved thus. Let s represent the required temperature of the body just congealed, $l =$ the number of degrees that express the heat required to reduce it to fluidity, $n =$ the specific heat of the solid, and $m =$ the specific heat of the fluid. Then $s+l : s :: m : n$. Whence $s = \frac{ln}{m-n} =$ the temperature from the natural zero in thermometrical degrees of the fluid. But because the actual fall of the thermometer is to be produced by cooling the solid, we must pay attention to its capacity. The quantity of heat required to produce a given change of temperature in a body is as its capacity; and consequently the changes of temperature, when the quantity of heat is given, will be inversely as the capacities: therefore, $n : m :: \frac{ln}{m-n} : \frac{ln}{m-n} = s$. which is the rule abovementioned.

"If the data l, m, and n, be accurately obtained by experiment, in any one instance, and the difference between the zero of Fahrenheit's scale and the natural zero he thence found in degrees of that scale, this difference will serve to reduce all temperatures to the numeration which commences at the natural *o*. So that s being known in all cases, if any two of the quantities l, m, or n, be given in any body, the other may be likewise had. For $l = \frac{sm-sn}{n}$; and $m = \frac{sn}{s-l}$ and $n = \frac{sm-lm}{s}$.

"To give an example of this curious rule, let it be required to determine how many degrees of refrigeration would absolutely deprive ice of all its heat? The degrees of heat necessary to melt ice are 130; and the specific heats of ice and water are as 9 to 10. The number 130 multiplied by 10, produces 1300, and divided by the difference between 9 and 10 quotes 1300: therefore if ice were cooled 1300 degrees below 32°, or to—1268 of Fahrenheit's scale, it would retain no more heat."

II. *Fluidity* is another effect of heat, and is capable of taking place in all bodies hitherto known, when the fire is carried to a certain pitch. Theories have been invented, by which fluidity was ascribed to the smoothness and round figure of the particles whereof bodies were composed, and solidity to an angular or irregular figure. It has also been ascribed to a strong-

115 Fluidity to be ascribed to the absorption of heat.

er degree of attraction between the parts of solids than of fluids. Dr Black, however, has shown, that in the case of melting ice, we are certainly to ascribe the acquired fluidity of the water to the absorption of heat. This was determined by a decisive experiment, in which he exposed a Florence-flask full of water to the atmosphere in a warm room, when he found that the heat in the air evidently left it, to flow into the ice in the bottle, and reduced it to fluidity. The air thus deprived of its heat, he felt sensibly descending like a cold blast from the bottle, and continuing to do so as long as any of the ice remained unthawed; yet after it was all melted, the temperature of the fluid was no more than 32°. Different degrees of heat are requisite for converting different solids into fluids, for which see the *Table of Degrees of Heat*.

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This theory receives an additional confirmation from the quantity of heat which is always known to be produced by the conversion of a fluid into a solid. And that this is really the case appears, 1. From what happens in

116 Sensible heat produced by the conversion of a fluid into a solid.

the congelation of waters, it appears that ice is formed very slowly, and with several circumstances which support the theory.—Thus, if we suppose equal quantities of water to the air, which is perhaps 10 below frost, and add to one of these a small quantity of salt or spirit of wine, and observe the cooling of each, we shall find them both grow gradually colder, until they arrive at the temperature of frost: after which the water containing the salt will continue to grow colder, until it has arrived at the temperature of the air, at the same time that only a small quantity of the other water is converted into ice. Yet were the common opinion just, it ought all to have been congealed by this time; instead of which, it is scarce grown a degree colder during the whole time. Its remaining at the same temperature for so long a time, shows that it has been communicating heat to the atmosphere; for it is impossible that any body can remain in contact with another that is colder, without communicating heat to it. Whence then comes this heat? There must be some source adding to the sensible heat of the water, so as to keep its temperature to the freezing point: and this source of heat must be very considerable; for it will continue to act for a very long time before the water is changed into ice; during all which time, even to the last drop, the water is not a degree colder than 32° of Fahrenheit's thermometer. This, therefore, is the *latent heat* of the water, which had formerly entered into it during its transition from ice to a fluid state.

117 Argument in support of the theory from water remaining fluid tho' cooled below 32°.

A still stronger argument is derived from the following experiment; which evinces that the fluidity of water really depends upon its latent heat, and that the sensible heat is only a mean or condition to its containing the latent heat. This experiment consists in exposing water contained in a covered beer-glass to the air of a cold frosty night; and when the atmosphere is at the temperature of perhaps 10° or 12° below frost, the water will acquire that temperature without freezing: so that the fluidity of the water does not altogether depend on the quantity of sensible heat contained in it. The congelation, however, may be brought on by touching it with a bit of ice, with the extremity of a wire, by a shock upon the board, or otherwise disturbing it; and we then find the temperature suddenly raised up to 32°. This shows plainly, that the water has a disposition to retain the quantity of latent heat, upon which its fluidity must immediately and necessarily depend; and it retains it with a certain degree of force, so as to keep the water fluid in a temperature below that in which it usually parts with the latent heat and congeals. By disturbing it, however, we instantly bring on the congelation, which cannot take place without an extrication of the latent heat; which then, being changed into the ordinary or moveable heat, raises the thermometer as usual. The quantity of heat discharged from the first small portion of ice formed in the water is sufficient to prevent any more latent heat from separating, and consequently from any more ice being produced till more of the sensible heat is abstracted.

This doctrine extends not only to such bodies as are actually converted from a solid to a fluid, or from

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118 Heat the cauſe of the ſoftneſs of bodies approaching to fluidity.

a fluid to a ſolid ſtate, but to ſuch as are in a kind of middle ſtate betwixt ſolidity and fluidity; for every degree of ſoftneſs depends on a certain degree of heat contained in the body. Thus, for inſtance, melted wax, allowed to cool ſlowly, ſoon becomes opaque and conſiſtent; but it muſt be colder ſtill before it attains its utmoſt degree of hardneſs. There is therefore a certain degree of heat below which every body is ſolid, and above which every one is fluid; the former being called the *congealing*, and the latter the *melting*, point of bodies.

119 Abſorption of heat the univerſal cauſe of fluidity.

By making experiments upon different ſubſtances, the Doctor was convinced that latent heat is the univerſal cauſe of fluidity; and the doctrine holds good in all the experiments that have hitherto been made upon ſpermaceti, bees-wax, and ſome of the metals. If they are melted, allowed to cool ſlowly, and a thermometer be immerſed into them, we find, that as long as they continue fluid, their ſenſible heat diminiſhes very faſt; but as ſoon as they begin to grow ſolid, the ſenſible heat continues greater than that of the air to which they are expoſed; and during all this time it is communicating heat to the air, without having its ſenſible heat diminiſhed; for the latent heat within the fluid gradually receives a ſenſible form, and keeps up the temperature, proving a ſource of ſenſible heat, which is communicated to the neighbouring bodies as well as the ſurrounding air. The ſoftneſs and ductility of bodies depend on this alſo.

120 Vapour formed by the abſorption of latent heat.

III. *Evaporation.* A third effect of the action of heat is that of converting bodies into vapour, by which they are rendered ſpecifically lighter than the ſurrounding atmoſphere, and enabled to riſe in it. To account for this, many theories have been invented; but that of Dr Black, who accounts for it, as well as fluidity from the abſorption of latent heat, is now univerſally received. The circumſtances by which he proves and illuſtrates his doctrine are the following:

1. When we attend to the phenomena of boiling water, in a tea kettle for inſtance, it may, when firſt put upon the fire, be about the temperature of 48° or 50°. In a quarter of an hour it will become heated to 212°. It then begins to boil, and has gained 162° of vapour in that time. Now, if the converſion of it into vapour depended on the quantity of ſenſible heat introduced, we may aſk how long it will be neceſſary to raiſe it all in vapour? Surely another quarter of an hour ſhould be ſufficient; but this is far from being the caſe. Dr Black made ſome experiments upon this ſubject in conjunction with another gentleman. Having the opportunity of what is called a kitchen-table or a thick plate of caſt iron, one end of which was made ſenſibly red-hot, they ſet upon this ſome iron veſſels with circular flat bottoms, of about four inches diameter, and which contained a quantity of water. The temperature of the water was noted, as alſo when it began to boil; and when the whole of it was boiled away, it was found, that when ſet on the table its temperature had been 54°; in four minutes it began to boil, and in that ſpace of time received 158° degrees of heat. Had the evaporation, therefore, depended merely on the quantity of ſenſible heat introduced, it ought to have been diſſipated entirely in a ſingle minute more. It was, however, 18 minutes in diſſipating; and therefore had received 807 degrees of heat before it was all evaporated. All this time, therefore, while the water continued to boil, it was receiving a great quantity of heat, which muſt have been flowing equally faſt out of it; for the veſſel was no hotter, and the iron plate continued equally hot, the whole time. The veſſels were of different ſhapes, ſome of them cylindrical, ſome conical, others widening upwards; one of the deſigns of the experiment being to ſhow how far the evaporation was retarded by the particular form of the veſſels. By ſuſpending a thermometer in the mouth of one of the evaporating veſſels, the heat of the ſteam was found to be exactly 212°; ſo that as the great quantity of heat abſorbed was found neither to have remained in the water, nor to have been carried away by the ſteam in a ſenſible manner, we have nothing left to ſuppoſe, but that it flew off as one of the component parts of the ſteam in a latent ſtate.

121 Experiments by Dr Black on the converſion of water into vapour.

2. In an experiment to ſhow the fixedneſs of the boiling point of water, Dr Black incloſed ſome of that fluid in a ſtrong vial having a thermometer in it, and ſtopped cloſe with a cork. By the application of heat he hoped now to be able to raiſe the thermometer ſome degrees above the boiling point, which would be the natural conſequence of the confinement of the ſteam. When this was done, he pulled out the cork, and ſuppoſed that the water would now all fly out in vapour: but in this he was totally diſappointed; a ſudden and very tumultuous boiling enſued, which threw out ſome of the water; but though ſome quantity of ſteam likewiſe iſſued, the quantity of water was not conſiderably diminiſhed. The vial had been heated to 20° above the boiling point, but almoſt inſtantly cooled down to 212°, when the cork was taken out.

3. Mr Watt, in making ſome experiments on the force of ſteam, had occaſion to uſe Papin's digeſter, with a pipe proceeding from its ſide; the orifice of which was ſhut with a valve preſſed down by one end of a lever. Thus he heated ſteam to 400° of Fahrenheit; after which, having ſuddenly ſtruck off the lever, a quantity of ſteam flew out with conſiderable noiſe, and with ſuch violence as to make an impreſſion on the ceiling of the room; but this noiſe gradually diminiſhed, and after ten minutes it ceaſed entirely; and upon opening the machine, he found the greateſt part of the water ſtill remaining.

122 Boiling point of water *in vacuo* determined by Mr Boyle.

4. The change of ſenſible into latent heat in the formation of vapour, appears ſtill more evident in the boiling of water *in vacuo*. Mr Boyle took a quantity of water which had been previouſly boiled to purge it of its air, and put it whilſt hot under the receiver of an air-pump. In conſequence of this it began again to boil, and continued boiling till it was only lukewarm, and it ſoon arrived at this temperature; ſo that in this caſe alſo the heat had diſappeared during the converſion of the fluid into vapour. Others have repeated the experiment, as Boerhaave, Muſchenbroek; and Robinſon, who lectures on chemiſtry in Glaſgow, ſays that the heat diminiſhes very faſt till it comes to 90° or 95°, which ſeems to be the boiling point of water *in vacuo*. As a conſiderable part of the heat thus diſappears, and is to be diſcovered neither in the water nor in the vapour, we muſt conclude that it enters the latter as part of its compoſition.

123 And by Mr Robinſon of Glaſgow.

5. Thus alſo we may underſtand ſome curious experiments made by Dr Cullen upon ether and other volatile

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latile fluids. He employed ſome perſons to make experiments upon the cold produced by evaporation; and willing to repeat them himſelf *in vacuo*, he put ſome of the moſt volatile liquors under the receiver of an air-pump. One of theſe was ether. It was contained in a glaſs, in which there was alſo placed ſome water. When the air was extracted, the ether began to boil, and to be converted into vapour, till it became ſo very cold that it froze the water contained in the veſſel, though the temperature of the room was about 50°. Here therefore there was a quantity of heat which diſappeared all of a ſudden; which it is plain could not be owing to its having any communication with that of the atmoſphere or other cold bodies, as they could not render it colder than they were themſelves. Ether therefore is to be conſidered as a fluid ſo volatile, that were it not for the preſſure of the atmoſphere it would be perpetually in the ſtate of vapour.

124 Dr Cullen's experiments on cold produced by evaporation.

125 Heat expelled in great quantity by the condenſation of vapour.

6. That this heat which enters into the vapour is not deſtroyed, but remains in a latent ſtate, is eaſily proved; for we find that a great quantity of heat is expelled from vapour when it is condenſed again to form the body it compoſed originally. This is eaſily aſcertained by obſerving the quantity of heat communicated to the water in the refrigeratory of a ſtill by any given quantity of liquid which comes over. Thus, if the refrigeratory contain 100 pounds of water, and the diſtillation be continued till only one pound has come over, ſuppoſing the water in the refrigeratory to have received 8° of heat; it is plain, that if the whole of the quantity thus received could be thrown into one pound of water, the latter would be heated to 800°; which is ſufficient to make an equal ſpace of iron red-hot. But that this quantity of heat is received by the water in the refrigeratory has appeared from ſeveral experiments, which ſhow that water, by being converted into vapour, abſorbs between 800° and 900° of heat.

126 Mr Watt's experiments on the evaporation of fluids *in vacuo*.

On this principle we may explain ſome curious experiments made by Mr Watt with regard to the evaporation of fluids *in vacuo*. That gentleman had formed a deſign of converting water into ſteam with leſs expence of fuel, which he imagined might be done by removing the preſſure of the air from the water, which he thought would thus require a much ſmaller quantity of fuel to convert it into vapour. Dr Black, however, perceiving that only the ſmall quantity of ſenſible heat the ſteam poſſeſſed could thus be carried off, informed him beforehand that his project would not be found attended with the advantages he imagined. The experiment, however, was made in the following manner: A ſtill was procured of tinned iron, the body of which reſembled that of a retort, with a veſſel ſerving as a condenſer; the whole apparatus being cloſe, excepting a little hole in the extremity of the condenſing veſſel. He firſt exhauſted this veſſel of air by holding the condenſer over the retort, in which ſome boiling water was contained, until it was entirely converted into ſteam. He then ſuddenly ſtopped the little hole, and removed the veſſels from the fire; when, after they were cooled, there was a pretty perfect vacuum formed by the condenſation of the ſteam. The retort was then put on the fire, and turned ſo that the pipe and condenſing veſſel ſhould hang downward; and plunging them into cold water, heat was applied to the ſtill till the water boiled, as could be known by the noiſe. It was kept boiling, till a quantity of ſteam was puſhed over and condenſed with a very gentle heat, the ſtill feeling little warmer than his hand. After a certain quantity had been diſtilled, the apparatus was removed, and he had noted the heat of the water in the refrigeratory; but though the ſteam all along came over with ſo gentle a heat, he found the quantity communicated to the water in the refrigeratory to be ſurpriſingly great, not leſs than 1000°; ſo that it would have been more than ſufficient to heat the quantity of liquor which came over red-hot.

127 Ignition a conſtant and ſteady effect of heat.

IV. *Ignition*, or the cauſing bodies to ſhine or emit light in the dark. This may be conſidered as a ſpecies of inflammation, and ſhall therefore be explained under that head: here we ſhall only obſerve, that ignition is a more ſteady and conſtant effect of heat than either the production of fluidity or vapour; and appears not only to be the ſame degree with regard to any particular body, but the ſame with regard to all kinds of matter. Dr Martin imagines, that a red-hot piece of iron is hotter than a red-hot piece of ſtone; but if you put into a crucible an hundred different kinds of matter, as metals, glaſs, &c. that are capable of bearing a red heat, they will all begin to appear luminous about the ſame time, and their brightneſs will increaſe equally as their heat increaſes. But it is difficult to know at what point this begins, as we have no way of aſcertaining the beginning or loweſt degree of ignition but by the effect it produces on our ſight, and we cannot be ſure that we perceive the loweſt degree of light; for we know that other animals ſee objects with ſuch light as appears perfect darkneſs to us. Sir Iſaac Newton's method of determining this has been already mentioned.

128 All ignited bodies equally hot.

129 Metals may become vaſtly hotter after they are brought into fuſion.

Dr Boerhaave entertained a notion, that ſome metals, after being once brought into a ſtate of fuſion, could be made no hotter; and propoſes the poſſibility of this as a queſtion, "Whether the heat of metals can be increaſed after they are melted?" There is not, however, the leaſt doubt but that their heat may be vaſtly increaſed after they are melted; and we know certainly that ſuch as are of eaſy fuſion may be heated to a vaſtly greater degree after being melted; and why may not thoſe requiring ſtronger heats be the ſame? We are ſure that this is the caſe with ſilver, which, after being melted, may be brought to ſuch a heat as to become too dazzling for the eye to bear it. If Boerhaave's opinion were juſt, it would be impoſſible to caſt any metal into moulds, becauſe it muſt loſe a little heat in being removed from the fire and in entering the mould; nor would they receive a proper impreſſion if they did not contain a greater quantity of heat than was neceſſary for their fuſion.

130 Ignition an univerſal effect of fire.

Ignition appears to be univerſal; and all bodies capable of ſupporting it without being converted into an elaſtic vapour that cannot be confined, are affected the ſame way. Water, which in its ordinary ſtate ſeems very little capable of enduring this heat, may be confined in ſtrong veſſels ſo as to become capable of melting lead, which is more than half way betwixt a red heat and that of boiling water. Experiments with the colipile ſhow alſo that it can be made red-hot; for when the ſteam paſſes through burning fuel, it can-

131 Water may be made ſufficiently hot to melt lead.

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not miſs of being made red hot. Dr Black has alſo frequently ſeen the vapour of water heated by throwing it into the aſh-pit of a furnace, ſo as to produce a very large and tranſparent flame in riſing up through the vent. There is reaſon therefore to conclude, that ignition is one of the more general effects of heat, only that ſome bodies are incapable of it until they be reduced to a ſtate of vapour.

132
Difference betwixt ignition and inflammation.

V. The laſt of the effects of heat here to be taken notice of is *inflammation*. It differs from ignition in this, that the bodies ſubject to the latter gradually grow cooler as ſoon as they are taken out of the fire, without undergoing any conſiderable change; while thoſe ſubject to inflammation become continually hotter and hotter, communicating a vaſt quantity of heat to others, and undergoing a kind of decompoſition themſelves, inſomuch, that by this means they have beeen thought to be reduced to their conſtituent principles or elements.

133
Inflammation decompounds but does not deſtroy bodies.

Some ſubſtances indeed ſeem to be an exception to this, as in the open air they burn totally away, without leaving any reſiduum or producing any ſoot. Theſe are ſpirit of wine, ſulphur, and eſpecially inflammable air; which laſt, by a proper mixture with dephlogiſticated air, may be ſo totally conſumed, that ſcarce a fiftieth part of the two will remain. On a careful examination of theſe ſubſtances, however, we find that there is by no means a total conſumption, or indeed, properly ſpeaking, any conſumption at all, at leaſt if we meaſure the quantity of matter by the weight of the ſubſtance employed.

134
Spirit of wine yields a great quantity of water by being burned.

Thus, if we are at pains to collect the vapour of burning ſpirit of wine, we will find, that an aqueous dew is collected, which ſometimes equals the ſpirit of wine itſelf in weight. With regard to ſulphur, the caſe is ſtill more evident; for the vapour of this, when collected, not only equals but greatly exceeds the weight of the ſulphur employed; and on burning dephlogiſticated and inflammable air together, as much water is found to be produced as nearly equals the weight of both airs.

135
Water produced by the deflagration of dephlogiſticated and inflammable air.

In like manner, when we collect the aſhes, water, ſoot, and oil, procured by burning any of the common inflammable ſubſtances, we will find, that they in general exceed the weight of the matter employed. The great waſte of bodies by fire, therefore, is owing to the diſſipation of the volatile principles they contain, which are carried off and rendered inviſible by being mixed with the atmoſphere.

136
Of the exiſtence of phlogiſton.

The proceſs of inflammation has long been explained from the preſence of a ſubſtance called *Phlogiſton* in thoſe bodies which are ſubject to it, and which is ſuppoſed to be the ſame in all bodies belonging to this claſs; the differences between them ariſing from the principles with which it is combined.

137
Denied by M. Lavoiſier.

This doctrine, which was firſt introduced by Stahl, has given occaſion to ſuch various and diſcordant theories, that the exiſtence of phlogiſton has been lately denied altogether by M. Lavoiſier, who brought in a new method of ſolving the phenomena of fire, heat, and ignition, without any aſſiſtance from this principle.

138
Arguments againſt it drawn from the increaſed weight of metals by calcination.

The foundation of M. Lavoiſier's doctrine is the increaſe of weight in metals by calcination. This increaſe he finds to be preciſely, or very nearly ſo, proportionable to the decreaſe of weight in the air in which they are calcined. His theory, therefore, is, that in the act of calcination, the pure part of the air, which he calls the *acidifying* or *oxygenous* principle, unites with the metal, and converts it into a calx.

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139
His theory of inflammation.

In like manner, in ſubſtances truly inflammable, the heat and flame are ſuppoſed to proceed from the union of the pure air, or the oxygenous principle, with the ſubſtance, and converting it into thoſe principles which are found to remain after inflammation. Thus the increaſed weight of the ſubſtance is eaſily accounted for; while the inflammation, in his opinion, is nothing more than a combination of the inflammable body itſelf with pure air, which has an attraction for it: and in confirmation of that it is urged, that when combuſtion is performed in empyreal or dephlogiſticated air, the whole of the latter is abſorbed; but in common atmoſpherical air only one-fourth, being the quantity of pure air contained in it.

140
Arguments for the non-exiſtence of phlogiſton, from the reduction of the calces of perfect metals without addition.

Other arguments in favour of this opinion are, that the calces of the perfect metals may be reduced without addition by the mere emiſſion of the oxygenous principle, (dephlogiſticated air); by an union with which they aſſume the form of a calx. Thus he evades a very ſtrong argument uſed by the oppoſite party; who adduced, as a proof of the exiſtence of phlogiſton, the uſe of charcoal in the reduction of metals to their proper form.

141
Diſpute betwixt Lavoiſier and Prieſtley.

A diſpute indeed took place betwixt M. Lavoiſier and Dr Prieſtley concerning the reduction of the whole of a mercurial calx formed by an union with the nitrous acid without addition; the Doctor maintaining that the whole could not be reduced by mere heat, but that a very perceptible quantity was always loſt: but on a thorough examination of the ſubject, the truth ſeemed rather to lie on M. Lavoiſier's ſide. See AEROLOGY.

142
Dr Lubbock's theory.

Another theory, ſomewhat ſimilar to that of Lavoiſier's, has been publiſhed by Dr Lubbock, in an Inaugural Diſſertation in 1784. In this he ſuppoſes two kinds of matter to exiſt in the univerſe; one he calls the *principium proprium*, the other the *principium ſorbile*; and it is this latter, which, according to our author, is the principle of mutability, or which by being united in various proportions with the other, forms bodies of all the different kinds we ſee in nature. It is this principle, therefore, which he ſuppoſes to be abſorbed in the calcination of metals, and not empyreal air, as M. Lavoiſier ſuppoſes; and he contends, that this ſame principle extends throughout the whole ſyſtem of nature, even to the utmoſt celeſtial bounds.

143
Diſputes concerning phlogiſton now entirely decided.

It would exceed the limits of this treatiſe to give an account of the various theories which have been invented, and the arguments uſed for and againſt them; nor indeed is there any occaſion for doing ſo, as late experiments have reduced the diſpute into a much narrower compaſs than before, and furniſhed the moſt deciſive arguments in favour of the exiſtence of phlogiſton.

144
Objections againſt the exiſtence of phlogiſton from its inviſibility and ſuppoſed want of gravity.

The greateſt objection to the belief of this principle was, that it could neither be ſeen nor felt by our ſenſes directly, nor diſcover itſelf indirectly by the weight it communicated to the bodies with which it was united; on the contrary, the latter always became lighter in proportion to the quantity they contained: ſo that it was imagined, inſtead of being poſſeſſed of any ſpecific gravity of its own, to be a principle of poſitive levity, ſuch as that of heat or light may be reaſonably ſuppoſed. This objection, however, is now intirely removed; and phlogiſton in the abſtract is found

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found to be no ſubtile principle capable of eluding our reſearches, but one very common, and eaſily met with, being no other than common charcoal. In the laſt

145 Common charcoal and phlogiſton the ſame.

edition of this work, under the article PHLOGISTON, it was ſhown, that inflammable air, deprived of its elaſticity, and combined with metallic ſubſtances, is really their phlogiſton; and that in the inflammable bodies commonly uſed, what we call their phlogiſton, is really their oil; and that which exiſts in charcoal, and cannot be driven off by diſtillation, is part of the empyreumatic or burnt oil of the ſubject which adheres ſo obſtinately. A ſimilar doctrine ſoon after appeared in the Philoſophical Tranſactions for 1782, and the identity of phlogiſton and inflammable air was clearly proved by Mr Kirwan. Still, however, it was inſiſted by

146 Deciſive proofs of this identity given by Dr Prieſtley.

the French philoſophers and others, that no *facts* had been adduced againſt M. Lavoiſier, nor any deciſive proofs appeared of the exiſtence of phlogiſton as a ſubſtance *per ſe*. Facts of this kind, however, have now been diſcovered by Dr Prieſtley, and are related under the articles AEROLOGY, CHARCOAL, PHLOGISTON, &c. It is ſufficient at preſent to mention, that he

147 Spirit of wine and metals convertible into charcoal.

has been able to convert the pureſt ſpirit of wine, and one of the hardeſt metals, viz. copper, as well as ſeveral others, into a ſubſtance entirely reſembling charcoal; that by means of the heat of a burning glaſs in vacuo, he has diſſipated this metallic charcoal, as well as the common kind, *entirely* into inflam-

148 Charcoal entirely diſſipated by heat into inflammable air.

mable air, with the aſſiſtance only of a little water, which ſeems neceſſary to make it aſſume the aerial form, and perhaps is the true ſolvent of it; and by a combination with the element of heat, with the aid of the charcoal, is enabled to reſiſt condenſation in the common way.* This inflammable air, when abſorbed by metallic calces, again reduces them to their metallic

* See *Elaſtic Vapour.*

149 Metallic calces reduced by inflammable air.

form: ſo that here is one fact by which the phlogiſton not only appears to our ſenſes, but we are able to aſcertain its quantity with the utmoſt preciſion. Nor can it here be any objection, that the reduced metal is lighter than the calx; for this only proves that the

150 Why metals are lighter in their metallic than in their calcined ſtate.

metallic earth, while a calx, is united to a heavy ingredient (the baſis of dephlogiſticated air), and in the latter to a light one, viz. charcoal, the baſis of inflammable air.

Another caſe in which the exiſtence of phlogiſton is made equally evident to our ſenſes, and where no ſuch objection can occur, is related under the article AEROLOGY, n° 112. It is there ſhown, that "by the

151 Dephlogiſticated air converted into aerial acid by charcoal.

loſs of one grain of charcoal of copper (formed by the union of ſpirit of wine with the metal), and which like common charcoal was conſumed without having any reſiduum, he reduced four ounce-meaſures of dephlogiſticated air till only one-ninth remained unabſorbed by water; and, again, with the loſs of one grain and a half of charcoal, ſix and an half meaſures of dephlogiſticated air were reduced till five and an half meaſures were pure fixed air."—Here, then, is an abſolute and undeniable evidence, that fixed air is compoſed of dephlogiſticated air, and charcoal or phlogiſton, and elementary fire. There were no other ingredients preſent, and the charcoal muſt either have been annihilated or diſpoſed of in the manner juſt mentioned: but the ſuperior weight of the fixed air evidently ſhows that ſome ingredient had been added to the dephlogiſticated air; and which increaſe was more than we can ſuppoſe to ariſe from the condenſation of the dephlogiſticated air during the operation, for this ſometimes amounted to no more than one-thirtieth part.

152 Objections drawn from the total combuſtion of dephlogiſticated air in ſome caſes.

The ſtrongeſt objection which can be made againſt the doctrine of phlogiſton may be drawn from the total conſumption of pure air in certain caſes of combuſtion, for inſtance, in that of phoſphorus, inflammable air, and iron. It muſt be obſerved, however, that in no caſe whatever is the air totally conſumed; and in that of inflammable air water is produced by the union of the baſis of the latter, that is charcoal, with the baſis of dephlogiſticated air, the oxygenous principle of M. Lavoiſier, and which appears to be one of the component parts of WATER. In the caſe of phoſphorus, the latter is converted into an acid; and in all probability a quantity of water is alſo produced, by which part of it is converted into cryſtalline

153 Little phlogiſton expelled from iron by being burnt in dephlogiſticated air.

flowers. The caſe of the iron, therefore, alone remains to be conſidered. Dr Prieſtley's experiments on this ſubject are related at length under the article AEROLOGY, n° 67 *et ſeq.* In them the iron burnt briſkly in dephlogiſticated air, which, according to the common theory, ſhould have indicated the expulſion of a great quantity of phlogiſton; yet the whole reſiduum, of which the fixed air, produced by the ſuppoſed union of the phlogiſton or principle of inflammability, was only a part, ſcarce amounted ſometimes to one-fourteenth of the air originally employed.

154 The objection inconcluſive.

The argument, however, inſtead of contradicting the exiſtence of phlogiſton, only ſhows, that in ſome caſes the diſſipation of a very ſmall quantity of phlogiſton is neceſſary to inflammation; or that the aerial principle may combine with the iron in its metallic ſtate. In this caſe only a very little quantity of the phlogiſton of the iron was diſſipated; for it was

155 Iron is not reduced to a calx by burning in dephlogiſticated air.

not reduced to a calx, but to that kind of ſcoriæ which flies off in ſcales by beating the metal when red-hot with an hammer. A deciſive proof of this was had by uniting iron thus combined with the baſis of dephlogiſticated air with inflammable air. By this the metal was indeed reduced to perfect

156 Water produced in the reduction of it by inflammable air.

iron again; but water was produced at the ſame time from the union of the baſis of the two airs, that of the inflammable air being capable of furniſhing a ſuperfluous quantity, which united with the other into the form of a fluid.

157 Heat produced in the combuſtion of inflammable bodies derived from the air.

The exiſtence of phlogiſton being thus proved, and its nature aſcertained, we may now proceed to determine the queſtion, Whether the great quantity of heat produced by the combuſtion of inflammable bodies proceeds from the bodies themſelves, or from the air which muſt be admitted to them in order to make them burn? That the heat in this caſe proceeds from the atmoſphere is evident; becauſe in all caſes of combuſtion there is a certain diminution undoubtedly takes place by means of the converſion of the dephlogiſticated part of the atmoſphere into fixed air. It is proved, under the article *ELASTIC Vapours*, that elementary fire is the univerſal cauſe of elaſticity in fluids. By uniting a certain quantity of it with any ſubſtance, the latter at length aſſumes an aerial or vaporous form; and it is this vapour alone which is inflammable*. Different vapours no doubt contain different quantities of theſe ingredients; but in all caſes the baſis of the dephlogiſticated part of the atmoſphere

* See the article *Flame.*

General Effects of Heat.

muſt unite with the phlogiſton of the inflammable body, or with ſomething elſe, ſo that a decompoſition may enſue: and it is this decompoſition which produces the heat and light; for then the fire contained in the
158 Too much phlogiſton prevents the heat from being intenſe.
atmoſphere having no longer any thing to abſorb it, muſt appear in its proper form. But in thoſe caſes where there is a great quantity of phlogiſton, and conſequently much fixed air produced, the latter abſorbs ſo much heat in a latent ſtate, that the quantity communicated to ſurrounding bodies muſt be greatly diminiſhed; and if an exceſs of this ingredient, not only fixed air, but the phlogiſticated kind and groſs ſmoke be alſo produced, this diminiſhes the heat ſtill farther by the great abſorption, and will even deſtroy it altogether. The remedy for this is either to diminiſh the quantity of phlogiſton, or to augment the quantity of air; which, by furniſhing a greater quantity of dephlogiſticated baſis, affords an opportunity
159 Too great a quantity of air has the ſame effect.
for the evolution of a greater quantity of heat. On the other hand, when the quantity of air is too great, the phlogiſtic matter cannot combine with the baſis of the pure air in ſufficient quantity to effect a decompoſition; and therefore the heat is abſorbed in a latent ſtate, and the fire goes out.

From this theory, which is farther illuſtrated under the articles FIRE, FLAME, HEAT, PHLOGISTON, &c. we may not only have a rational idea of the manner in which inflammation is generally accompliſhed, but ſee
160 Why the ſolar heat and that of electricity are ſo intenſe.
why a fire may be put out both by too great a quantity of fuel, and by too great a quantity of air. We may alſo ſee why the ſolar beams and electric fluid, which contain no phlogiſtic matter, excite a much more powerful heat than any we can raiſe in our hotteſt furnaces. The difference between ignition and inflammation will now likewiſe appear; ſuch bodies as are capable only of ignition containing little or no phlogiſton, but inflammable bodies a great deal.

161 Table of the various degrees of heat.
The following table ſhows the moſt remarkable degrees of heat from the congelation of mercury to that of Mr Wedgewood's hotteſt furnace.

Mercury freezes at - - -	40
Weak ſpirit of wine - -	32
Brandy at - - -	10
Cold produced by ſnow and ſalt mixed	0
Strong wine freezes at -	20
Vinegar freezes at - -	27
Water freezes at - -	32
Temperature of ſpring and autumn	50
Ordinary ſummer weather -	65
Sultry heat - - -	75
Heat of human blood -	97 to 100
Feveriſh heat - - -	108
Bees wax melts - - -	142
Serum coagulates - - -	156
Spirit of wine boils - -	174
Water boils - - -	212
Tin melts - - -	408
Biſmuth melts - -	460
Oil of vitriol boils - -	550
Oil of turpentine boils -	561
Lead melts - -	585
Quickſilver and linſeed-oil boil -	600
Iron begins to ſhine in the dark -	635
Iron ſhines briſkly in the dark -	750
Iron ſhines in the twilight -	884
Iron red-hot from a common fire	1050
Red heat fully viſible in day light according to Mr Wedgewood -	1077
Heat by which his enamel colours are burnt on - - -	1857
Braſs melts - - -	3807
Swediſh copper melts - -	4587
Fine ſilver melts - -	4717
Fine gold melts - -	5237
Leaſt welding heat of iron -	12777
Greateſt ditto - -	13427
Greateſt heat of a common ſmith's forge - - -	17327
Caſt iron melts - -	17977
Greateſt heat of Wedgewood's ſmall air-furnace - - -	21877
Extremity of the ſcale of his thermometer - - -	32277

Elective Attraction.

SECT. II. *Of the Doctrine of Elective Attraction, and of the different Objects of Chemiſtry.*

162 Chemical attraction.

BEFORE we proceed to give a general theory of the changes which happen upon the mixtures of different bodies together, or expoſing them ſingly to heat, we muſt obſerve, that all depend on certain qualities in bodies, by which ſome of them are apt to join together, and to remain united while they have an opportunity. The cauſe of theſe qualities is totally unknown; and therefore philoſophers, after the example of Sir Iſaac Newton, have expreſſed the apparent effect of this unknown cauſe by the word *attraction*. From them the word has been adopted by the chemiſts, and is now generally uſed in ſpeaking of the phenomena which are obſerved in the mixture of different ſubſtances; but to diſtinguiſh it from other kinds, it is uſually called *Elective*.

This attraction is not equally ſtrong between all ſubſtances; in conſequence of which, if any body is compounded of two others, and another is preſented to it which has a greater attraction for one of the component parts than they have for one another, the ſubſtance will be *decompounded*. A new compound is then formed by the union of that third ſubſtance with one of the component parts or *elements* (if we pleaſe to call them ſo) of the firſt. If the attraction between the body ſuperadded and either of the component parts of the other is not ſo ſtrong as that between themſelves, no decompoſition will enſue; or if the third ſubſtance is attracted by both the others, a new compoſition will take place by the union of all the three.

163 Objects of chemiſtry how claſſed.

The objects of chemiſtry, as we have already obſerved, are ſo various, that an enumeration of them all is impoſſible. To eaſe the mind, therefore, when ſpeaking of them, and render more uſeful any thing that is ſaid or wrote on chemiſtry, it is neceſſary to divide them into different claſſes, comprehending in each claſs thoſe bodies which have the greateſt reſemblance to one another, and to which one common rule applies pretty generally.—The diviſion formerly uſed, was that of vegetables, animals, and minerals; but this has been thought improper, as there are many ſubſtances in each of thoſe kingdoms which differ very widely from one another, and which are by no means ſubject to the ſame laws. The moſt approved method, Salts. thod, at present, of arranging the objects of chemistry, is into salts, earths, metals, inflammable substances, waters, animal and vegetable substances.

Sect. III. *Salts.*

164 Salts. Salts are either *fusible*, that is, capable of abiding the fire, and melting in a strong heat, without being dissipated; or *volatile*, that is, being dispersed in vapour with a small heat. Their other properties are, that they are soluble in water: not inflammable, unless by certain additions; and give a sensation of taste when applied to the tongue.

The most general characteristic of salts is, that they are all soluble in water, though some of them with much more difficulty than others. Most of them have likewise the property of forming themselves, in certain circumstances, into solid transparent masses of regular figures, different according to the different salt made use of, and which are termed *crystals* of that salt. In this state they always contain a quantity of water; and therefore the utmost degree of purity in which a salt can be procured, is when it has been well crystallized, and the crystals are freed of their superfluous moisture by a gentle heat. They generally appear then in the form of a white powder.

165 Phenomena attending their solution. In the solution of salts in water, the first thing observable is, that the water parts with the air contained in it; which immediately rises to the top in the form of bubbles. This, however, is most remarkable when the salt is in the dry form we have just now mentioned, because there is always a quantity of air entangled among the interstices of the powder, which rises along with the rest; and this discharge of air is sometimes so great, as to be mistaken for an effervescence. From this, however, it is essentially different. See Effervescence.

Another thing observable in the solution of salts is, that a considerable change happens in the temperature of the water in which they are dissolved; the mixture becoming either a good deal warmer or colder than either the salt or the water were before. In general, however, there is an increase of cold, and scarce any salt produces heat, except when it has been made very dry, and deprived of that moisture which it naturally requires; and thus the heating of salts by being mixed with water may be explained on the same principle with the heat produced by quicklime. See Quicklime.

After salt has been dissolved in a certain quantity by water, no more of that salt will be taken up unless the water is heated; and as long as the heat continues to increase, the salt will be dissolved. When the water boils, at which time it has attained its greatest heat, and will take up no more salt, it is then said to be *saturated* with that salt. This, however, does not prevent it from taking up a certain quantity of another salt, and after that perhaps of a third, or fourth, without letting go any of the first which it had dissolved. How far this property of water extends, has not yet been ascertained by experiments.

To the above rule there is only one exception known as yet; namely, common sea-salt: for water dissolves it in the very same quantity when cold as when boiling hot. It has been said by some, that all deliquescent salts, or those which grow moist on being exposed to the air, had the same property: but this is found to be a mistake.

This property of solubility, which all the salts possess in common, renders them easily miscible together; and the property by which most of them shoot into crystals, renders those easily separable again which have no particular attraction for one another. This is likewise rendered still more easy by their requiring different proportions of water, and different degrees of heat, to suspend them; for by this they crystallize at different times, and we have not the trouble of picking the crystals of one out among those of the other. 166 Mixture and separation of salts.

The manner in which the solution of salts in water is effected, is equally unaccountable with most of the other operations of nature. Sir Isaac Newton supposed that the particles of water got between those of the salt, and arranged them all at an equal distance from one another: and from this he also accounts for the regular figures they assume on passing into a crystalline form; because, having been once arranged in an orderly manner, they could not come together in disorder, unless something was to disturb the water in which they were suspended; and if any such disturbance is given, we find the crystals are by no means so regular as otherwise they would have proved. Others have thought that these figures depend on a certain *polarity* in the very small particles into which the salt is resolved when in a state of solution. These things, however, are merely conjectural; neither is it a matter of any consequence to a chemist whether they are right or wrong. 167 Hypothesis concerning the solution of salts.

Though solution is that operation which salts undergo the most easily, and which should seem to affect them the least of any, a repetition of it proves nevertheless very injurious to them, especially if it is followed by quick evaporation; and the salt, instead of being crystallized, is dried with a pretty strong heat. Newman relates, that a pound of sea-salt was reduced, by 13 solutions and exsiccations, to half an ounce; and even that was mostly earth. Where solution is required, therefore, it ought always to be done in close vessels, in which also the subsequent evaporation should be performed, (see Evaporation); and in all cases where crystallization is practicable, it ought to be preferred to violent exsiccation. 168 Salts destructible by repeated solutions.

The two great divisions of salts are into acids and alkalies. The former of these are known by their peculiar taste, which is called *acid* or *sour*. They are not found in a solid form; neither are any of them, except the acids of vitriol, of tartar, of phosphorus, and of borax, capable of being reduced to solidity. The others, when highly concentrated, that is, brought to the utmost degree of strength of which they are capable, always become an invisible vapour, permanently elastic, until it comes in contact with water, or some other substance with which they are capable of uniting. For such acids the name of *salts* seems less proper, as we can scarcely say that a *vapour*, which is already much more fluid than water, can be *dissolved* in that element. 169 Acids.

The acids are divided into the mineral, the vegetable, and the animal; expressing their different origin, or where they are most commonly to be found. The mineral acids are commonly reckoned three; the

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Salts.

vitriolic, the nitrous, and the marine. To this the acid of borax ought to be added; but its weakness makes it much less taken notice of as an acid than the others. A Swedish chemist, however, Mr Scheele, hath lately added several others, which are afterwards taken notice of.

The vegetable kingdom affords only two distinct species of acids, at least without the assistance of some chemical operation. The one appears fluid, and when concentrated to the utmost degree becomes an invisible vapour. This is produced from fermented liquors, under the name of *vinegar*. An acid similar to this, and which is thought not to be essentially different from it, is extracted from most vegetables by distillation with a strong fire. The other is likewise a consequence of fermentation; and crusts on the bottom and sides of casks in which wine is put to depurate itself. In its crude state it is called *tartar*; and when afterwards purified, is called the *cream*, or crystals, of tartar. As for the various acids produced in the different chemical processes to be afterwards related, we forbear to mention them at present, it being justly suspected that some of them are artificial.

The animal acids, which have hitherto been discovered, are only two; the acid of ants, and that of urine, which is also the acid of phosphorus. The first of these is volatile; and consequently must be supposed a vapour when in its strongest state: the other is exceedingly fixed; and will rather melt into glass than rise in vapours. Besides these, it is said an acid is contained in blood, in wasps, bees, &c.: but no experiments have as yet been made on these to determine this matter with any degree of precision.

170 Alkalies.

The alkalies are of two kinds; fixed and volatile. The fixed kind are subdivided into two; the vegetable, and mineral or fossil alkali. The vegetable is so called, because it is procured from the ashes of burnt vegetables; the fossile, because it is found native in some places of the earth, and is the basis of sea-salt, which in some places is dug out of mines in vast quantity. They are called *fixed*, because they endure a very intense degree of heat without being dissipated in vapour, so as even to form a part of the composition of glass. The volatile alkali is generally obtained by distillation from animal substances. In its pure state this alkali is perfectly invisible; but affects the sense of smelling to such a degree, as not to be approached with safety.

171 Different action of alkalies and acids.

The acids and alkalies are generally thought to be entirely opposite in their natures to one another. Some, however, imagine them to be extremely similar, and to be as it were parts of one substance violently taken from each other. Certain it is, that when separated, they appear as opposite to one another as heat and cold. Their opposite action indeed very much resembles that of heat and cold, even when applied to the tongue; for the alkali has a hot, bitter, burning taste, while the acid, if not considerably concentrated, always gives a sensation of coldness. In their action too upon animal substances, the alkali dissolves, and reduces the part to a mucilage; while the acid, if not very much concentrated, tends to preserve it uncorrupted.

172 Neutral salts.

If an alkaline salt, and moderately strong acid in a liquid state, be mixed together, they will immediately unite; and, provided the alkali has not been deprived of its fixed air, their union will be attended with a very considerable effervescence: (see AEROLOGY.) If the alkali has been deprived of air, no effervescence will ensue, but they will quietly mix together; but if a due proportion of each has been added, the liquor will neither have the properties of an acid nor an alkali, but will be what is called *neutral*. The bringing the liquor into this state, is called *saturating* the acid or alkali, or combining them to the point of saturation.

If the liquor after such a saturation be gently evaporated, a saline mass will be left, which is neither an acid nor an alkali, but a new compound formed by the union of the two, and which is called a *perfect neutral salt*. The epithet *perfect* is given it, to make a distinction between the salts formed by the union of an acid and an alkali, and those formed by the union of acids, with earthy or metallic substances; for these will likewise unite with acids, and some of the compounds will crystallize into regular figures; but, because of their weaker union with these substances, the salts resulting from combinations of this kind are called *imperfect*.

173 Vegetable colours changed by acids and alkalies.

All acids, the volatile sulphureous one excepted, change the blue infusions of vegetables, such as violets, to a red; and alkalies, as well as some of the imperfect neutrals, change them to green. This is the nicest test of an acid or alkali abounding in any substance, and seems the most proper method of determining whether a solution intended to be neutral really is so or not.

174 Differences in the degrees of attraction between acids and alkalies

Though between every acid and alkali there is a very strong attraction, yet this is far from being the same in all; neither is it the same between the same acid and alkali in different circumstances of the acid. When the acids are in a liquid state, and as free as possible of inflammable matter, between which and the nitrous and vitriolic acids there is a very strong attraction, the vitriolic will expel any of the rest from an alkaline basis, and take its place. Thus, if you combine the acid of sea-salt, or marine acid, to the point of saturation, with the fossil alkali, a neutral salt will be formed, which has every property of common salt: but, if you pour on a certain proportion of the vitriolic acid, the acid of sea-salt will immediately be expelled; and the liquor, upon being evaporated, will contain not the neutral salt formed by an union of the marine acid with the alkali, but another consisting of the vitriolic acid joined with that alkali, and which has quite different properties from the former.

When the acids and alkalies are applied to one another in a liquid state, the vitriolic acid always shows itself to be the most powerful; but when applied in a solid form, and urged with a violent heat, the case is very much altered. Thus, the acid of borax, commonly called *sal sedativus*, is so weak as to be disengaged from its basis by every acid applied in a liquid form, that of tartar alone excepted; but if even the vitriolic acid combined with an alkali be mixed with this weak acid, then exsiccated, and at last urged with a vehement fire, the vitriolic acid will be disengaged from its basis, and rise in vapours, leaving the weaker acid in possession of the alkali. The same thing happens on adding the phosphorine or urinous acid,

acid, or the acid of arſenic, &c. to combinations of the vitriolic or other acids with alkaline ſalts.—When the acids are in a liquid ſtate, therefore the moſt powerful is the vitriolic; next the nitrous; then the marine; then vinegar; acid of ants; and laſtly the ſal ſedativus and tartar, which ſeem to be nearly equal in this reſpect.—If they are applied in a ſolid form, the moſt powerful are the ſal ſedativus and phoſphorine acid; then the vitriolic, nitrous, marine, and vegetable acids.

When they are reduced to vapour, the caſe is exceedingly different; for then the marine acid appears to be the moſt powerful, and the vitriolic the leaſt ſo of any. It is impoſſible, however, to preſerve the vitriolic acid in the form of vapour, without combining it with a certain quantity of inflammable matter, which muſt neceſſarily deſtroy its ſtrength. Dr Prieſtley found, that the marine acid, when reduced to vapour, was capable of diſuniting the nitrous acid from a fixed alkali.

Though the vitriolic acid ſometimes aſſumes a ſolid form, it is by no means eaſy to reduce it to this ſtate by mere concentration, without the aſſiſtance of nitrous acid. Baldaſart, however, pretends that he diſcovered, in the neighbourhood of a volcano, a pure and icy oil of vitriol, from which nothing could be precipitated by alkaline ſalts; though there is certainly very great reaſon to doubt the accuracy of this obſervation. Of late the nitrous acid has alſo been found capable of aſſuming a ſolid form. This was firſt obſerved by M. Bernhard in diſtilling a very large quantity of the acid. At that time he perceived a white ſalt adhering to the inſide of the receiver, which on examination proved to be the acid of nitre in a concrete form; being extremely corroſive, emitting red vapours copiouſly on being expoſed to the air, and at length totally evaporating in it. Its ſpecific gravity, however, was far inferior to that of the glacial oil of vitriol.

175 Acids unite with phlogiſton.

The acids have the property of uniting themſelves to many other ſubſtances beſides fixed alkalies, and forming neutral compounds with them. Of theſe the chief is the principle of inflammability or phlogiſton. In the vitriolic, nitrous, and phoſphorine acids, the attraction for this principle is very ſtrong; ſo great, that the two former will even leave a fixed alkali to unite with it. In the marine acid it is leſs perceptible; in the liquid vegetable or animal acid ſtill leſs; and in the acid of tartar, and ſal ſedativus, not at all.

176 With metals and earth.

Beſides this, all acids will diſſolve metallic and earthy ſubſtances: with theſe, however, they do not in general unite ſo firmly with alkaline ſalts; nor do they unite ſo ſtrongly with metals as with earths.

177 Elective attractions.

In general, therefore, we may expect, that after having diſſolved a metal in any acid whatever, if we add an earthy ſubſtance to that ſolution, the acid will quit the metal, which it had before diſſolved, to unite with the earth. In this caſe the ſolution will not be clear as before, but will remain muddy, and a quantity of powder will fall to the bottom. This powder is the metalline ſubſtance itſelf, but deprived of one of its component parts; and in this caſe it is ſaid to *precipitate* in the form of a *calx*.

If to this new ſolution of the earthy ſubſtance in an acid liquor, a volatile alkaline ſalt, not deprived of its fixed air, is added, the acid will quit the earth, and unite with the alkaline ſalt. The earth thus diſengaged will again *precipitate*, and lie at the bottom in fine powder, while the volatile alkali and acid remain combined together, and the liquor again becomes clear.

The attraction between volatile alkalies and acids is conſiderably leſs than between fixed alkalies and the ſame acids. If, therefore, a fixed alkali be now added to the liquor, the volatile alkali will be ſeparated, and the acid will unite with the fixed alkali. The volatile alkali indeed, being perfectly ſoluble in water, cannot precipitate, but will diſcover its ſeparation by the pungent ſmell of the mixture; and upon evaporating the liquor, the volatile alkali will be diſſipated, and a ſaline maſs, conſiſting of the acid and fixed alkali, will remain.

178 Detonation of nitre.

Laſtly, If the acid employed was the nitrous, which has a ſtrong attraction for the principle of inflammability, if the ſaline maſs be mixed with a proper quantity of inflammable matter, and expoſed to a ſtrong heat, the acid will leave the alkali with vaſt rapidity, combine with the inflammable matter, and be deſtroyed in flame in a moment, leaving the alkali quite pure.

179 Exceptions to the above rules.

Though the abovementioned effects generally happen, yet we are not to expect that they will invariably prove the ſame whatever acid is made uſe of; or even that they will be the ſame in all poſſible variety of circumſtances in which the ſame acid can be uſed.—The acid of tartar is one exception, where the general rule is in a manner reverſed; for this acid will quit a fixed alkali for an earth, eſpecially if calcined, and even for iron. If lead, mercury or ſilver, are diſſolved in the nitrous acid, and a ſmall quantity of the marine acid is added, it will ſeparate the ſtronger nitrous acid, and fall to the bottom with the metals in form of a white powder.—The vitriolic acid, by itſelf, has a greater attraction for earthy ſubſtances than for metals; and greater ſtill for fixed alkaline ſalts than for either of theſe: but if quickſilver is diſſolved in the nitrous acid, and this ſolution is poured into a combination of vitriolic acid with fixed alkali, the vitriolic acid will quit the alkali to unite with the quickſilver. Yet quickſilver by itſelf cannot eaſily be united with this acid. The reaſon of all theſe anomalies, however, is fully explained in the following ſection.

§ 1. *Of the Operations of Solution and Precipitation.*

The chemical ſolution of ſolid bodies in acid or other menſtrua, is a phenomenon which, though our familiarity with it has now taken off our ſurpriſe, muſt undoubtedly have occaſioned the greateſt admiration and aſtoniſhment in thoſe who firſt obſerved it. It would far exceed the limits of this treatiſe to ſpeak particularly of all the various circumſtances attending the ſolution of different ſubſtances in every poſſible menſtruum. The following are the moſt remarkable, collected from Mr Bergman's Diſſertion on Metallic Precipitates.

180 Phenomena attending the ſolution of a metal.

1. On putting a ſmall piece of metal into any acid, it is diſſolved ſometimes with violence, ſometimes gently, according to the nature of the menſtruum and of the metal to be diſſolved.

2. The nitrous acid is the moſt powerful in its action

Solution and Preci-pitation.

tion upon metallic ſubſtances, when unaſſiſted by heat. So great indeed is the violence with which this acid ſometimes acts, that the metal, inſtead of being diſſolved, ſeparates inſtantaneouſly from it in the form of a calx or powder ſcarce ſoluble in any menſtruum, at the ſame time that the heat, effervefcence, and noxious vapours iſſuing from the mixture, render it abſolutely neceſſary to moderate the action of the menſtruum, either by dilution or cold, or both. In other caſes, however, as when put to gold or platina, the nitrous acid has no effect until it be united with the marine, when the mixture acts upon thoſe metals, which neither of the acids ſingly would touch.

181 Nitrous acid the moſt violent in its operation.

182 Vitriolic acid acts more weakly.

3. The action of the vitriolic acid, though in the higeſt degree of concentration, is more weak. It does not readily attack ſilver or mercury unleſs aſſiſted by a boiling heat, nor will even that be ſufficient to make it act upon gold or platina.

183 Marine acid generally more weak than either, except when dephlogiſticated.

4. The action of marine acid, unleſs on ſome particular ſubſtances, is ſtill more weak; but when dephlogiſticated, or deprived of part of the phlogiſton eſſential to its conſtitution as an acid, it acts much more powerfully, and diſſolves all the metals completely.

184 The reſt of the acids much weaker ſtill.

5. The other acids, as thoſe of fluor, borax, with ſuch as are obtained from the animal and vegetable kingdoms, are much inferior in their powers as ſolvents, unleſs in very few inſtances.

185 Different degrees of ſolubility in metals.

6. Metals vary very much in their degrees of ſolubility; ſome yielding to almoſt every menſtruum, and others, as has been already obſerved, being ſcarce acted upon by the moſt powerful.

186 Solution ſometimes promoted by abſtracting a certain proportion of phlogiſton.

7. Zinc and iron are of the former kind, and gold and ſilver of the latter, eluding the marine; and gold, unleſs in one particular caſe, viz. when aſſiſted by heat in a cloſe veſſel, the action of the nitrious acid alſo. Theſe metals, however, which in their perfect ſtate reſiſt the action of the moſt powerful menſtrua, may be diſſolved much more readily when deprived of a certain quantity of their inflammable principle. But though the ſeparation of this principle in ſome degree renders metals more ſoluble, the abſtraction of too much of it, particularly in the caſe of iron and tin, renders theſe metals almoſt entirely inſoluble. Manganeſe is the moſt remarkable inſtance of this power of the phlogiſtic principle, in depriving metals of their ſolubility by its abſence, or reſtoring it to them by its preſence; for this ſubſtance, when reduced to blackneſs, cannot be diſſolved by any acid without the addition of ſome inflammable matter; but when by the addition of phlogiſton it has become white, may be diſſolved in any acid.

187 But is totally prevented by taking away too much: exemplified in mangan-eſe.

188 Solution of metals attended with an effervefcence.

8. The diſſolution of metals by acids, even to their very laſt particle, is attended by a viſible effervefcence: this is more perceptible according to the quickneſs of the ſolution; but more obſcure, and ſcarcely to be ſeen at all, when the ſolution proceeds ſlowly.

189 Various kinds of elaſtic fluids extricated.

9. The elaſtic fluids extricated by theſe ſolutions are various, according to the nature of the acid and of the metal employed. With the nitrous, the fluid produced is commonly that called *nitrous air*; with vitriolic and marine acids the produce is ſometimes inflammable air, ſometimes otherwiſe, according to the nature of the metal acted upon.

10. Heat in a greater or ſmaller degree is always produced during the diſſolution of metals; and the degree of it is in proportion to the quantity of the matter and the quickneſs of the ſolution; and hence, in ſmall quantities of metal, and when the ſolution proceeds very ſlowly, the temperature of the maſs is ſcarcely altered.

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190 Heat produced during the diſſolution of metals.

11. The calces of metals either yield no air at all, or only the aerial acid, unleſs when urged by a violent heat almoſt to ignition; when, by means of vitriolic or nitrous acid, they yield a quantity of pure air, after other elaſtic fluids, ſuch as vitriolic, nitrous, or phlogiſticated air. None of the dephlogiſticated air is uſually produced by the marine acid in conjunction with metallic calces.

191 Little air can be obtained from metals when calcined.

12. The ſolutions of ſome metals are coloured, others are not. The colour of the former is only that which is proper to the calx, but rendered more vivid by the moiſture. Thus ſolutions of gold and platina are yellow; thoſe of copper, blue or green; ſolutions of nickel of a bright green; but thoſe of cobalt are red, although the calx is black. We may obſerve that even this red colour may be heightened to blackneſs. Iron moderately calcined is green; but this rarely continues upon further dephlogiſtication. The white calces of ſilver, lead, tin, biſmuth, arſenic, antimony, and manganeſe, are diſſolved without colour; but ſolutions of lead, tin, and antimony, are ſomewhat yellow, unleſs ſufficiently diluted. Mercury, however, forms a ſingular exception to this rule; for the orange-coloured calx of this metal forms a colourleſs ſolution. The metals yielding coloured ſolutions are gold, platina, copper, iron, tin, nickel, and cobalt; the reſt, if properly depurated, give no tinge. A ſolution of ſilver is ſometimes of a blue or green colour at firſt, although there be no copper preſent; the vitriolic acid becomes blue with copper; the nitrous may be made either blue or green at pleaſure; the marine varies according to the quantity of water with which it is diluted. Manganeſe, when too much dephlogiſticated, renders both the vitriolic and marine acids purple.

192 Various colours of metallic calces.

193 Bergman's account of the cauſe of chemical ſolution.

With regard to the cauſe of chemical ſolutions, our author obſerves, that though attraction muſt be looked upon as the fundamental cauſe, yet we may alſo lay it down as a maxim, that no metal can be taken up by an acid, and at the ſame time preſerve the whole quantity of phlogiſton which was neceſſary to it in its metallic ſtate. A certain proportion of the principle of inflammability therefore may be conſidered as an obſtacle which muſt be removed before a ſolution can take place. Thus, of all the acids, the nitrous attracts phlogiſton the moſt powerfully, and ſeparates it even from the vitriolic. A proof of this may be had by boiling ſulphur ſlowly in concentrated nitrous acid. At length all its phlogiſton may be ſeparated, and the vitriolic acid will remain, deprived of its principle of inflammability. The extraordinary ſolvent powers of this acid, therefore, is conformed to the peculiarity of its nature in this reſpect. For this menſtruum diſſolves metals for ſolution with the greateſt eaſe, moſt commonly without any aſſiſtance from external heat; which in ſome inſtances would be hurtful, by ſeparating too much of phlogiſton, as appears in the caſe of iron, tin, and antimony; all of which may be ſo far dephlogiſticated by the nitrous acid, as to be rendered extremely difficult of ſolution: for this reaſon it is very often neceſſary, as has already been obſerved, to temper the activity

194 Solution impeded by too great a quantity of phlogiſton.

159 Sulphur dephlogiſticated by nitrous acid.

196 Calces of ſome metals prepared by nitrous acid almoſt inſoluble ever afterwards.

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activity of this menſtruum by water. The vitriolic acid requires a boiling heat before it can act upon ſilver or mercury. The reaſon of this is, that by means of the heat, the watery part of the menſtruum is diminiſhed, its power is thereby increaſed, and the connection of the metallic earths with the inflammable principle diminiſhed. Marine acid, which contains phlogiſton as one of its conſtituent principles, muſt neceſſarily have little or no effect on thoſe metals which retain their principle of inflammability very obſtinately. But its watery part being diminiſhed by boiling, it aſſumes an aerial form, and powerfully attracts a larger quantity of phlogiſton than before; ſo that in a vaporous ſtate it will diſſolve metals, particularly ſilver and mercury, which in its liquid form it would ſcarce be brought to touch. When dephlogiſticated as much as poſſible, it attracts phlogiſton with prodigious avidity, diſſolving all metals by its attraction for their phlogiſton, and, uniting the inflammable principle to itſelf, reſumes the ordinary form of marine acid. When dephlogiſticated by means of nitrous acid in aqua regis, it diſſolves gold and platina. On the ſame principles may we account for its inferiority in power to the other acids.

197 Why the vitriolic acid cannot act on lead, ſilver, &c. without a boiling heat.

198 Why marine acid acts on ſome metals and not on others.

199 Why ſome metals are more ſoluble than others.

It has already been obſerved that the metals differ much in their degrees of ſolubility, which is owing to the various, degrees of force with which they retain their phlogiſton. Thoſe called perfect metals effectually reſiſt calcination in the dry way. In this operation, the fire on the one hand, the great cauſe of the volatility of bodies, ſtrenuouſly endeavours to expel the phlogiſton; on the other hand, the baſis of the dephlogiſticated part of the atmoſphere (the acidifying principle of M. Lavoiſier, and the *principium ſorbile* of Dr Lubbock) attracts the calx ſtrongly. Experience, however, ſhows, that theſe two forces united, cannot decompoſe gold, ſilver, or platina to any conſiderable degree. All the other metals yield to theſe forces when united, but not ſingly. Iron and zinc retain their inflammable principle ſo ſlightly, that any acid immediately acts upon them; but if the other metals be properly prepared for ſolution by being calcined to a certain degree, the acid will immediately take them up. Any further privation, however, would be injurious, and precipitate what was before diſſolved. Thus the nitrous acid, when added to a ſolution of tin or antimony in marine acid, by its extraordinary attraction for phlogiſton carries off ſuch a quantity of it, that the calces of the metals are immediately precipitated.

200 Why nitrous acid precipitates a ſolution of tin or antimony.

201 Different kinds of air produced during the diſſolution of metals.

The various elaſtic fluids which reſemble air, and which are produced in plenty during the diſſolution of metals, may be reduced to the following, *viz.* thoſe extricated by the vitriolic, nitrous, and marine acids, fluor acid, vinegar, alkaline ſalts, and hepar ſulphuris.

202 Pure vitriolic acid cannot be reduced into an aerial form but by a combination with phlogiſton.

Pure vitriolic acid expoſed to a violent heat, is indeed reſolved into vapours, but of ſuch a nature, that when the heat is gone, they condenſe again into an acid liquor of the ſame nature as before. But if any ſubſtance be added which contains phlogiſton in a ſeparable ſtate, an elaſtic fluid is produced by means of fire, which is ſcarcely condenſible by the moſt extreme cold, unleſs it comes in contact with water. This is called the volatile ſulphureous acid, or vitriolic acid air, which may be totally abſorbed by water. In this caſe the bond of union betwixt it and the phlogiſton is ſo weak, that the latter ſoon flies off totally, and common vitriolic acid is regenerated.

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203 Nitrous acid more obviouſly changed.

The nitrous acid undergoes a ſimilar change in a more obvious manner. Let a piece of ſilver, for inſtance be put into a dilute nitrous acid, and the ſurface of the metal will inſtantly be covered with innumerable bubbles, which ariſing to the top of the liquor, there burſt; and if collected, are found to be nitrous air. The nitrous acid ſaturates itſelf with phlogiſton more completely than the vitriolic; therefore the elaſtic fluid produced, or nitrous air, does not unite with water, and ſcarce retains any veſtige of an acid nature. The vitriolic acid, however, differs from the nitrous in this reſpect, that the phlogiſton is abſorbed by the latter even beyond the point neceſſary to obliterate its acid nature. In proof of this, our author adduces the decompoſition of hepatic by means of nitrous air.

204 Why nitrous air does not unite with water.

205 Phenomena exhibited by the marine acid.

The marine acid exhibits different phenomena. It naturally contains phlogiſton, and therefore can by its means be reſolved into a kind of air ſomewhat ſimilar to that produced by the vitriolic acid when artificially united to the ſame principle, and which has the ſame property, *viz.* that of remaining permanently elaſtic as long as it is kept from the contact of water. But as the acid we ſpeak of naturally contains phlogiſton, there is no neceſſity of adding more to produce this effect. In the mean time, the marine as well as nitrous air, when in its expanded ſtate, attracts phlogiſton, and that with wonderful avidity.

206 Of the dephlogiſticated marine acid.

When the marine acid is dephlogiſticated, it yields another elaſtic fluid of a reddiſh brown colour, having an odour like that of warm aqua regia. This does not unite with water, or only in very ſmall quantity: and by the addition of a proper proportion of phlogiſton may be reduced again to common marine acid. It is ſaid that the marine acid may be dephlogiſticated by lead as well as by manganeſe, the nitrous acid, and arſenic.

207 Of the fluor acid.

The fluor acid abounds with phlogiſton, and therefore may, without any adventitious matter, be reduced to an elaſtic fluid. This air is eaſily diſtinguiſhed from all others by its corroſion of glaſs whilſt hot.

208 Why vinegar may be reduced into air without addition.

Vinegar alſo contains phlogiſton; and for that reaſon, when well dephlegmated, may be reduced without addition into a permanently elaſtic fluid, called acetous air.

209 Heat and not phlogiſton the principle of elaſticity.

All theſe fluids ſeem to be nothing elſe, according to Mr Bergman, than the acids themſelves expanded by phlogiſton. "Perhaps (ſays he) the matter of heat alſo enters their compoſition." The experiments lately made on theſe ſubjects, however, have put it beyond all doubt, that the expanſive principle is not phlogiſton but heat; nevertheleſs, it ſeems highly probable, that theſe elaſtic fluids do really conſiſt of the acid united to phlogiſton, and expanded by heat. This is alſo the caſe with the cauſtic volatile alkali, now called alkaline air.

210 Sulphur exiſts in hepatic air.

In the hepatic air, it has been ſhown by Mr Bergman, that ſulphur exiſts which contains phlogiſton; and there is little reaſon to doubt that the expanſive power here is the ſame as in other caſes. See HEPATIC AIR.

The heat generated during the ſolution of metals is by Mr Bergman ſuppoſed to be owing to the matter

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of heat which had been fixed in the metals; but it may with much more reason be supposed to proceed from the acid.

211 Heat in solution most probably proceeds from the solvent liquor.

Dr Black has demonstrated, that heat is universally the principle of fluidity; and all fluids, whether acid or not, are found to contain a great quantity of it. It is not probable that solids, even the most inflammable, contain an equal quantity; for it is always observed, that bodies in becoming fluid absorb heat, and throw it out again on becoming solid. Acids in all probability contain a much greater quantity than what is necessary to their fluidity; for we see that the nitrous acid, when poured upon snow, parts with as much heat as is necessary to dissolve the snow, at the same time that it still retains its fluidity. The case is not so with common salt, which is a solid: for though, in a mixture of salt and snow, the latter absorbs as much heat from the salt as is necessary for its own liquefaction; yet the salt could not be held in solution by a liquid of this temperature, were it not that an additional quantity is perpetually absorbed from the adjacent bodies, particularly the atmosphere. But were it possible to prevent this adventitious increase of heat, there is not the least reason to believe that the salt would be dissolved; for the strongest brine, when reduced to the temperature of 0 of Fahrenheit, is decomposed, the salt falling to the bottom in powder, and the water being converted into ice. Add to this also, that the cold produced by spirit of nitre and snow is much more intense than that produced by common salt and snow; which undoubtedly shows, that a

212 Solid bodies do not part with so much heat as fluids.

solid does not readily part with as much heat as a fluid, and consequently cannot be supposed to contain as much. The solution of metals in acids also demonstrates, that the solid substance has not parted with heat, but absorbed it; for as soon as the solution becomes solid again, *i. e.* when it crystallizes, the temperature becomes higher than before.

213 Why little or no elastic fluid is obtained from metallic calces.

The calces of metals have not that quantity of phlogiston that is necessary for their metallic state, but yet are not entirely destitute of it; therefore, in their solution, scarce any elastic fluid is generated, unless the fire be continued after exsiccation. Such as contain aerial acid, discharge it immediately in the same form as they had received it. It is remarkable, that Dr Priestley mentions a calx of lead, which, with the acid of phosphorous, produced an inflammable air. By means of the nitrous acid and evaporation to dryness, a pure air is produced. Sometimes a small portion of vitriolic acid air is obtained by means of a proper degree of fire from vitriolic acid, but a far greater quantity of pure air.

214 Metallic solutions contain a calx of the metal with various degrees of phlogiston.

The solutions made by the menstrua abovementioned, contain a metallic calx intimately united with the acid, the quantity of phlogiston left being various according to the difference of the menstrua and of the temperature; but the performance of the operation either with or without intense heat, frequently occasions a remarkable difference. That metals are less calcined by the marine than by the nitrous acid, appears from pouring concentrated nitrous acid on tin or antimony; but the difference, if it actually does take place, is less visible in other metals.

Some modern chemists have denied this calcination of metals by solution. They have insisted, that the perfect metals ought to be excepted, as they do not yield to the most intense fire. On this subject, however, it may be observed, 1. That during their solution nitrous air is always generated, and that of a very perfect kind, which cannot happen without phlogiston; but in this case there is nothing present which can yield phlogiston except the metals. Therefore, 2. The metals, when precipitated from their menstrua by fixed alkalis, both with respect to their external appearance and internal properties, appear to be calcined. Thus the precipitate of gold refuses to unite with mercury, and may be dissolved by marine acid and other simple menstrua, and that without the production of any elastic fluid. 3. Glass may be stained by these calces; but no metal in its perfect state can be taken up by glass.

215 Reasons for believing that metals are calcined by phlogiston.

216 Why the calces of the perfect metals may be reduced without addition.

The common objection is, that the calces of the perfect metals may be reduced by heat alone without the addition of charcoal. Many theories have been invented to solve this phenomenon. Some have supposed, that the matter of heat and light are the same with the phlogiston, and that thus the calces are reduced in the same manner as by charcoal or other substances usually termed *phlogistic*. But in this case we ought to find the calces of the imperfect metals also reduced by a long continuance of heat, as well as the more perfect; which, however, has never yet been known to take place. Some, among whose number is Dr Lewis, have imagined, that the porosity of the vessels, particularly those made of earthen ware, may be such as to admit the passage of phlogistic vapours through them; and he instances the revival of globules of lead in the middle of pieces of glass upwards of an inch in thickness, and that where there was not the least appearance of a crack. But from an experiment of Mr Kirwan's to be afterwards related, it is much more probable that the reduction is effected by means of the phlogiston contained in one part of the calx attracted by another; by which means the latter is reduced to a perfect metal, while the former becomes somewhat more dephlogisticated. In consequence of this it appears, that the calx of the perfect metals is never totally reduced: for if the operation be performed in a glass retort, the bottom of it is always stained; which indicates the existence of a calx, in however little quantity.

217 Difficulty concerning the amalgamation of silver solved by Bergman.

The following fact, Mr Bergman says, has been proposed to him as an inextricable dilemma. "Silver cannot amalgamate with mercury except when in its metallic state, yet both salited and nitrated silver are taken up by mercury; it is therefore not calcined by the acids, but adheres to them in its metallic form." This, however, may be easily solved in the following manner. It is well known that the calx of copper, dissolved in the vitriolic acid, is precipitated in its metallic form on the addition of iron, and that by means of a double elective attraction; for the iron, dissolving in the acid, would form an inflammable air by its phlogiston, were not the copper present which takes it up, and thereby becomes insoluble as long as it retains it; but mercury has a stronger attraction for acids than silver: if therefore salited or nitrated silver be triturated with mercury, the silver must be precipitated in a metallic state, and the mercury be calcined by being dissolved. This also takes place, provided there be moisture sufficient to suffer the elective attractions

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tions to operate. The ſuperabundant mercury greedily takes up the comminuted ſilver precipitate; and the *arbores Dianæ* are nothing more than ſuch an amalgam cryſtallized. But although the acids cannot take up any metal while it retains its full proportion of phlogiſton, various metallic ſalts are able to effect that ſolution. Thus nitrated or ſalited mercury, boiled in water together with the crude metal, can take up a certain portion of it without dephlogiſtication; and the latter of theſe ſalts, even in the *via ſicca*, becomes a mercurius dulcis, which contains at the ſame time a crude and a calcined mercury.

218 Phlogiſton the cauſe of colour in metallic ſolutions.

Perfect ſolutions ſhould in general be tranſparent; but ſome, as has been already mentioned, are diſtinguiſhed by a peculiar colour. That phlogiſton is the chief cauſe of colour appears from hence, that the black calx of mangancſe tinges vitriolic acid of a red colour; but on the addition of ſugar the tinge is entirely deſtroyed. Nitrous acid is rendered blue by copper; but when the metal is added in conſiderable quantity, it becomes of a very deep green. The marine acid, which dephlogiſticates the copper leſs, is yet made green; but by dephlegmation may be ſo condenſed as to become brown. Mr Bergman has ſometimes ſeen a ſolution of ſilver green, without the preſence of the ſmalleſt particle of copper. This depends on the abſorption of nitrous air: for let ſmoking nitrous acid be diluted, on the addition of a certain quantity of water it will be of a deep green; by a greater, blue; and upon a ſtill greater, becomes limpid. By means of the water, the nitrous air is extended to a greater ſpace; and this attenuation gradually increaſed varies the colours. Hence we ſee why nitrous acid is made green by a large quantity of copper.

219 Attraction of phlogiſton the cauſe of cauſticity.

Metals dephlogiſticated by acid ſolvents powerfully attract phlogiſton; nay, nitrated ſilver and mercury, and ſalited antimony, corrode animal ſubſtances, in order, as our author ſuppoſes, to extract it. "This metallic cauſticity (ſays he), which is only to be moderated by phlogiſton, ought to be carefully diſtinguiſhed from the acid cauſticity, which is repreſſed by alkalies, and the alkaline, which is mitigated by acids. Colours vary according to the quantity of phlogiſton preſent; and ſome experiments ſhow, that by a ſufficient quantity all colour is entirely deſtroyed.

220 Phenomena attending the precipitation of metals by alkaline ſalts.

All metals may be precipitated by alkaline ſalts; which, by their ſuperior power of attraction, ſeparate them from their menſtrua; but their difference with regard to their nature and preparation alters the nature of the precipitate. With the cauſtic fixed alkali the calces fall almoſt entirely pure, but loaded with water. The weight is found to be increaſed by the water, and perhaps (ſays Mr Bergman) by the matter of heat; but yet leſs than by the aerial acid. With the aerated fixed alkali, by means of a double decompoſition, the aerial acid unites to moſt calces. The volatile alkali, which naturally contains phlogiſton, ſometimes phlogiſticates the precipitate. It throws down a black or white precipitate of mercury; nay, it makes the orange-coloured precipitate white. Gold receives its fulminating quality from this precipitant, as is afterwards to be explained. The alkali, which is commonly called *phlogiſticated*, generally precipitates metals with an increaſe of weight.

The acids frequently occaſion precipitates, and that for various reaſons. By means of elective attraction, mercury, ſilver, and lead, are taken from the nitrous acid by the addition of the marine or vitriolic. Theſe acids form with the metals new compounds which are difficult of ſolution in water; they are therefore precipitated in greater or leſſer quantity according to circumſtances. The nitrous acid is capable of decompounding ſalited tin and antimony by dephlogiſticating the calx of the metals too much; for when theſe are too much calcined, they cannot be diſſolved in any menſtruum, as has been already obſerved.

221 Precipitates occaſioned by acids, and why;

Metallic ſolutions are ſometimes diſturbed by the neutral ſalts formed by an union of alkalies with acids. Thoſe which contain the vitriolic or marine acids decompoſe ſolutions of ſilver, mercury, or lead, in nitrous acid, and precipitate the metals. By forming a triple combination, the vegetable as well as the volatile alkali, though ſaturated with vitriolic, nitrous, or marine acid, precipitate platina from aqua regia; but when the baſis is mineral alkali, the ſalt has no power of this kind. Some metallic ſalts can decompoſe others, and precipitate their baſes; which may happen whether the acid be different in the two ſalts or not. Solution of gold affords an example of each of theſe caſes. This is precipitated by martial vitriol; the reaſon of which will appear from conſidering the nature of the precipitate: for this, when well waſhed and dried, not only ſhows many ſhining gold-coloured particles, but alſo unites with mercury by trituration, diſſolves in aqua regia, but not in marine acid alone, together with other circumſtances which evince a complete reſuſcitation of the gold. Martial vitrol, in its ordinary ſtate, contains phlogiſton, but very looſely adhering; ſo that the calx of gold may eaſily take it from the ſolution to ſupply the loſs it had ſuſtained during the ſolution. That this is the true foundation of the proceſs, appears alſo from the following circumſtances, that the weight of the gold is exactly recovered, and that dephlogiſticated vitriol will not precipitate this metal. The reaſon that the ſurrounding aqua regia leaves this precipitate untouched is, that the menſtruum is diluted and weakened by a large quantity of water; for upon boiling it gently, ſo as to expel part of the water, the menſtruum recovers its ſolvent power, and takes up the precipitate again.

222 By the perfect neutral ſalts;

223 By a triple combination.

224 Some metallic ſalts decompoſe others.

225 Why ſolution of gold is precipitated by green vitriol;

226 But not by this ſalt when dephlogiſticated.

227 Why ſolution of gold is precipitated by ſolution of tin.

It is ſomewhat more difficult to explain the reaſon why the ſolution of gold in aqua regia ſhould be precipitated by a ſolution of tin in the ſame menſtruum. Here Mr Bergman firſt ſuppoſed that the the tin had attracted a ſuperabundance of acid, and taken it from the gold; which being therefore deſtitute of its proper quantity, muſt fall to the bottom: but on employing a ſolution containing a ſuperabundant aqua regia, the ſame precipitation took place. The cauſe is therefore not in the menſtruum. On examining the precipitate itſelf, we find nothing like the metallic ſplendor of gold, but that it entirely reſembles a calx. It is eaſily found by its weight, indeed, that it cannot conſiſt entirely of gold; and in fact chemical examination ſhows that it conſiſts partly of tin. It cannot be diſſolved by the marine acid alone, but is eaſily taken up by the addition of a little nitrous acid. It ſcarcely unites with mercury by trituration. Theſe properties ſeem to indicate, that the gold has ſo far received phlo-

228 This precipitate conſiſts partly of tin.

Solution and Precipitation.

giſton as to reſiſt the marine acid until it receive the aſſiſtance of the nitrous; but its earthy appearance, and difficulty of uniting with mercury, evince that it is not in its complete metallic form. The following therefore, according to our author, ſeems to be the moſt eaſy and rational explanation. The ſolution of tin neceſſary for this operation muſt retain as much phlogiſton as it poſſibly can, in a conſiſtence with ſolubility. This is dropped into a ſolution of gold very much diluted; by which means the phlogiſton remaining in the tin is more looſened, and of conſequence more eaſily attracted by the gold calx, which is thereby brought to a ſtate approximating to completion, ſo that it can no longer be retained by the menſtruum; and the ſame happens to the tin, by means of the dephlogiſtication; they muſt both therefore fall to the bottom mixed intimately with one another. It is probable, ſays he, that in this caſe it is the tin which prevents the matter from uniting with mercury.

229
Precipitation of metals by one another, owing to a double elective attraction.

The metals precipitate one another after a certain order, which is the ſame in all acid menſtrua. This precipitation is occaſioned by a double elective attraction; for the metal to be precipitated exiſts in the ſolution in a calcined ſtate; but being reduced by the phlogiſton of the precipitant falls to the bottom, while at the ſame time the precipitant becomes ſoluble by calcination: but if the precipitant has been calcined ſo that a part of it being inſoluble is mixed with the precipitate, the metallic ſplendor is wanting, and it puts on an earthy appearance. A pure precipitate is of the ſame weight with the metal before ſolution. The mixed precipitates are leſs frequently met with, yet gold precipitated by tin exhibits one of that kind.

230
Variations in the order in which the metals precipitate one another.

Though the order in which the metals precipitate one another is conſtant and never inverted, yet there are many anomalous circumſtances which occur in the matter. Thus zinc conſtantly prevails over iron; iron over lead; lead over tin; tin over copper; copper over ſilver; ſilver over mercury, *&c.* yet it ſometimes happens, that a metal which, according to the general rule, precipitates another in its metallic ſtate from one menſtruum, precipitates it from another in form of a calx, and not at all from a third. Thus zinc precipitates iron from marine acid in its metallic ſtate, but from the nitrous only in form of a clax. Tin is precipated by lead from the marine acid in its metallic ſtate, but is not thrown down from the nitrous acid; and from the acetous is precipitated even by iron and zinc in form of a clax; ſolution of lead in vinegar is not precipitated by iron.

231
Mineral alkali why preferred as a precipitant by Mr Bergman.

232
How he prepared his cauſtic alkali.

233
Various precipitates of gold.

In Mr Bergman's experiments on this ſubject he employed the mineral alkali, as the degree of its ſaturation with fixed air was more conſtant. When he had occaſion for a cauſtic alkali, he prepared it by a ſmall quantity of burned lime kept in a cloſe bottle; and the goodneſs of it was proved by its occaſioning no precipitation in lime water. Phlogiſticated alkali, or that by which Pruſſian blue is prepared, was alſo made uſe of. With theſe he made the following obſervations. Gold diſſolved in aqua regia is precipitated by cauſtic alkali almoſt black; by the aerated, yellow, as well as by the phlogiſticated, unleſs ſome iron be preſent, which frequently happens; but the whole of the gold is ſcarce ever precipitated, ſo that the weight cannot be aſcertained.

234
Mineral alkalies precipitate platina imperfectly.

Neither the cauſtic nor aerated mineral alkali precipitate one half of platina diſſolved in aqua regia; the precipitate is of an orange colour, which on drying becomes brown. An over-proportion of alkali rediſſolves the precipitate, and the liquor becomes more dark; nay, the precipitation is ſo imperfect, that the matter ſeems to be diſſolved even by neutral ſalts. The phlogiſticated alkali does not precipitate the depurated ſolution, nor even make it turbid, but heightens the colour in the ſame manner as an exceſs of alkali.

235
Precipitates of ſilver.

Solution of ſilver in nitrous acid lets fall a white precipitate by the aerated alkali; brown by the cauſtic, and of an obſcure yellow. By the nitrous and marine acids it lets fall a white precipitate, which with the former conſiſts of more diſtinct particles, which grow black more ſlowly with the light of the ſun.

236
Of mercury.

Salited mercury lets fall a red precipitate, or rather one of a ferruginous colour, by aerated alkali; but of a more yellowiſh or orange colour by the cauſtic. Nitrated mercury prepared without heat, yields a ferruginous precipitate with mineral alkali; a black with cauſtic: and when prepared with heat, it yields to cauſtic alkali an orange or reddiſh yellow precipitate. By phlogiſticated alkali it is precipitated from all acids of a white colour; but turns of a browniſh yellow when dry. Salited mercury is very ſparingly precipitated by this alkali. The precipitate by phlogiſticated alkali is again diſſolved, if too much of the precipitant be made uſe of.—Corroſive ſublimate muſt be very cautiouſly precipitated by cauſtic, as well as aerated fixed alkali; for the part ſeparated may again be diſſolved by a large quantity of water. When too much alkali is uſed, a new compound ariſes of a peculiar nature.

237
Precipitates of lead.

Solution of lead in ſpirit of nitre is precipitated down white by aerated, cauſtic, or phlogiſticated alkali. By uſing too much alkali, the precipitate by the phlogiſticated kind is diſſolved with a browniſh yellow colour. Vitriol of lead and ſolution of lead in marine acid are precipitated white.

238
Of copper;

Blue ſolution of copper in ſpirit of nitre is precipitated of a bright green by aerated fixed alkali; by the cauſtic of a greyiſh brown, which grows reddiſh by age. By phlogiſticated alkali copper is precipitated of a greeniſh colour, which grows afterwards of a browniſh red, and upon exſiccation almoſt black. The aerial acid takes up a ſmall quantity of copper during the precipitation, which is again depoſited by the heat of boiling.

239
Of iron;

Aerated fixed alkali precipitates iron of a green colour from vitriolic and marine acid; but the precipitate becomes of a browniſh yellow, eſpecially on exſiccation; with the cauſtic alkali it approaches more to black. In the precipitation ſome part is held in ſolution by the aerial-acid, when the mild alkali is uſed. With phlogiſticated alkali a Pruſſian blue is formed.

240
Of tin;

Tin is precipitated of a white colour by every alkaline ſalt, even by the phlogiſticated kind; but at length ſome blue particles appear in the mixture: ſo that the whole, when collected and dried, appears of a light blue colour. That theſe blue particles are occaſioned by iron appears by calcination; for they become ferru-

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ferruginous, and obey the magnet. Our author has always found a proportion of iron in tin.

241 Precipitates of biſmuth; Biſmuth is thrown down of a fine white by water and alkalies, particularly the former; phlogiſticated alkali throws down a yellow powder, which being mixed with blue particles occaſioned by iron, at length appears green. This yellow ſediment eaſily diſſolves in nitrous acid.

242 Of nickel; Nickel is precipitated of a whitiſh green by fixed alkalies; by the phlogiſticated alkali of a yellow; and by exſiccation it is condenſed into a dark brown maſs.

243 Of arſenic; Arſenic diſſolved in acids, which prevent too great dephlogiſtication, may, to a certain degree, be precipitated white by the fixed alkali, even when phlogiſticated, but the ſediment is found ſoluble in water; yet nitrous acid, either alone, or joined with the marine, generally dephlogiſticates the arſenical acid, which thereby becomes unfit for ſeparation. Arſenic diſſolved in marine acid, with the aſſiſtance of a little nitrous acid, depoſited a white ſediment on the addition of a large quantity of phlogiſticated alkali. The ſediment was mixed with Pruſſian blue. This was diſſolved in water, and freed by frequent filtration from the blue particles; and at length, on evaporating to dryneſs, yielded a ſemipellucid maſs.

244 Of cobalt; Cobalt diſſolved in acids is thrown down by fixed alkali, whether aerated or cauſtic, of a reddiſh blue, which grows darker on exſiccation, eſpecially when the former alkali has been uſed. Phlogiſticated alkali throws down a powder of almoſt the ſame colour, which, upon exſiccation, becomes of a reddiſh brown.

245 Of zinc; Zinc is precipitated white by aerated and cauſtic fixed alkalies, as alſo by the phlogiſticated alkali; but this laſt becomes of a citron colour on exſiccation: a ſmall portion of aerial acid may eaſily eſcape during the precipitation.

246 Of antimony; Antimony is precipitated white by alkalies. When the phlogiſticated alkali is uſed, ſome blue particles are almoſt always precipitated at the ſame time, though the regulus had been prepared without any iron. This operation ſhould be cautiouſly conducted, leſt ſome part be taken up by the alkaline ſalt.

247 Of mangaheſe. Mangeneſe procured by reduction from common magneſia nigra, generally renders menſtrua brown, and with aerated alkali yields a yellowiſh brown ſediment; with the cauſtic, one ſtill darker; with the phlogiſticated, firſt a blue, then a white, powder is ſeparated, the mixture of which renders the maſs a black green. To obtain a pure and white calx of mangeneſe, we muſt diſſolve in pure vinegar the precipitate thrown down by cauſtic alkali; for there ſtill remains a quantity of iron which is taken up by the aerial acid. This acetous ſolution contains little or nothing of iron. That metal may alſo at firſt be ſeparated by a ſmall quantity of volatile alkali.

The common ſolution of the regulus is not perfectly precipitated by the aerated alkali; and upon evaporating the remaining liquor ſpontaneouſly to dryneſs, grains of a metallic ſplendor, and not unlike copper, are depoſited on the glaſs. The nitrous acid attracts theſe readily, though they are only partially diſſolved by it; but on the addition of zinc, nothing falls beſides the mangeneſe, though at firſt it is a little reddiſh. With phlogiſticated alkali, we obtain a yellow precipitate like pure mangeneſe, provided the ſolution has depoſited the iron when too much dephlogiſticated by age. But the new ſolution yields a precipitate almoſt like that which is obtained from common regulus. The yellow ſediment may be diſſolved in water.

248 On the cauſe of ſuch great variations in the weight of precipitates. The following is Mr Bergman's table of the quantities of precipitate of different metals, thrown down from various menſtrua by the different alkalies. "On comparing the weights (ſays he), a queſtion occurs concerning the cauſe of ſuch enormous differences; and it is plain, that this cauſe muſt be ſought for in the precipitates themſelves.—The fixed alkali ſaturated with aerial acid, when added to the ſolution, is taken up by the more powerful menſtruum; and the weaker is of courſe expelled, and is abſorbed by the calx as it falls, in greater or leſſer quantity according to circumſtances. That this is actually the caſe is eaſily demonſtrated:—Let a bottle containing a quantity of nitrous acid be accurately weighed. Let there be put into it, for inſtance, 132 parts of lead precipitated by aerated alkali; and not only an effervеſcence will be obſerved, which continues until the very laſt particle is diſſolved, but when the ſolution is finiſhed, a deficiency of weight is diſcovered, which amounts nearly to 21, and which is undoubtedly owing to the extrication of aerial acid. But 132—21=111; a weight which ſtill conſiderably exceeds that of the metal. Upon diſtillation nearly eight of water are diſcovered. There yet remain therefore three, which by violent heat are increaſed by ſeven; for 132 of the calx well calcined yield 110. The whole increment of weight then does not depend on the water and aerial acid. The ſame thing is evinced by conſidering the precipitate of lead by the cauſtic alkali; in which caſe there can be no aerial acid, nor does any effervеſcence accompany the ſolution. If we ſuppoſe the quantity of water equal in both caſes, yet even on this ſuppoſition the whole exceſs of weight is not accounted for; for 116—8=108. It is therefore probable, that the matter of heat is attached to the calx (A).—In proof of this opinion, and that cauſtic alkalies contain the matter of heat, our author adduces ſeveral arguments, of which the following is the ſtrongeſt.—"

249 Argument in favour of the weight of precipitates being augmented by the matter of heat. "Let the heat occaſioned by the mixture of any acid and cauſtic alkali be determined by a thermometer; let then an equal portion of the ſame menſtruum be ſaturated with a metal; afterwards, on the addition of an equal quantity of cauſtic alkali, it will be found, either that no heat is generated, or a degree very much leſs than before.—Some of the matter of heat therefore is taken up and fixed, which alſo generally makes the colours of the precipitates more obſcure; and in diſtillation with ſal-ammoniac, communicates to the volatile alkali the quantity that had been taken away."

250 Inſufficient. In this inſtance alſo, however, our author ſeems to have been deceived. It has already been obſerved, that in all ſolutions generating heat, it moſt probably comes from the fluid. Acids contain a quantity ſufficient

(A) This increaſe of weight is with more probability to be aſcribed to a remainder of the acid.

Solution and Precipitation. ficient not only for their own fluidity, but for rendering solid bodies fluid alfo. After they have diffolved the metal, however, this fuperfluous quantity is employed; and when the cauftic alkali is added, if in a folid form, it is again employed in giving fluidity to the alkali; or if the alkali be already diffolved, the increafed quantity of fluid makes the heat extricated lefs perceptible.

"What has been faid of lead (continues our author), is alfo true of the other metals, a few excepted, which feem to take up little or no aerial acid; fuch are tin, antimony, gold and platina.—But fome pre-

251 A quantity of the menftruum retained by fome precipitates. cipitates retain alfo a quantity of the menftruum. Thus, corrofive mercury, precipitated by aerated alkali, retains a portion of marine acid, which cannot be wafhed off by water; but, by cauftic alkali, the precipitate may be obtained, either free of the acid altogether, or in a great meafure. In this cafe, as in many others, the aerial acid feems to generate a triple falt, fcarce at all foluble. The prefence of the marine acid is eafily difcovered by folution of filver in ni-

252 Difference in the precipitates of mercury. trous acid, if the menftruum has been pure. Hence we obferve another difference in mercury precipitated from marine acid, according as we employ the aerated or cauftic alkali; the latter, well wafhed, and put into volatile alkali, is fcarcely changed in colour; but the former inftantly grows white, generating a fpecies of fal-alembroth, but containing fo little marine acid as not to be eafily foluble in water. The calces which retain any of their former menftruum, generally give over on diftillation a fmall portion of fublimate. The mercurial calx juft mentioned, expofed to a fufficient degree of heat, is partly reduced to crude mercury, partly to mercurius dulcis, by means of its remaining marine acid. This mercurius dulcis did not exift in the precipitate; for in that cafe it would be eafily difcovered by acids in which it is not foluble, and would grow black with cauftic alkali, neither of which take place, fo that it muft be generated during the diftillation."

253 Advantages to be derived from the examination of metallic precipitates. Mr Bergman concludes his differtation, with an enumeration of the advantages refulting from the careful examination of metallic precipitates.—Thefe are 1. That thus the theory of the operation will be more perfectly underftood. 2. We may difcover the more ufeful and remarkable properties. 3. A foundation is thereby laid for effaying in the moift way, from the bare knowledge of the weights. "It may be objected (fays he), that the doctrine of the weights is very fallacious; that they vary in different precipitates; that by imperfect precipitation fomething remains in the liquor; and that fometimes extraneous matters remain in them. All this is true; but if the mode of operation be the fame, the refults of the experiments will be equally conftant. Thus, let us fuppofe that a certain quantity of metal *a*, precipitated in a certain manner, makes a weight *b*; if that fame manner be exactly employed, we may fairly conclude, that a quantity of precipitate *nb*, occurring in any cafe, is correfpondent to a quantity of perfect metal *na*; though, in the fundamental experiment, the precipitation is either incomplete, or fome extraneous matter may be prefent. 4. The nature of metals is thus illuftrated. Platina, nickel, cobalt, and manganefe, are fuppofed by fome to derive their origin from a mixture of other metals. But if iron neceffarily enters into the compofition of platina, when the latter is diffolved in aqua regia, it ought to yield a Pruffian blue on the addition of phlogifticated alkali; which indeed is the cafe when common platina is employed, but not with that which is well depurated.

254 Platina is not compofed partly of iron; In like manner, if iron, adhering very obftinately to nickel, formed a great part of the latter, the precipitates obtained from it by alkalies could not differ from martial precipitates fo much as they do in colour,

255 Nor regulus of nickel; weight, and other properties. The fame holds true of cobalt and manganefe. The regulus obtained from the latter contains about 0.08 of iron, which affects the mixture in the following manner. An hundred

256 Cobalt or manganefe pounds diffolved in an acid menftruum, yields, by treatment with phlogifticated alkali, a powder confifting

257 Quantity of precipitate obtained from manganefe by phlogifticated alkali. partly of blue, partly of brownifh yellow particles, equal in weight to 150 pounds; but eight pounds of iron yield 48 of Pruffian blue, nearly 1/3 of the whole mafs of precipitate: whence it follows, that 100 parts of pure manganefe yield to phlogifticated alkali fcarcely 111; *i. e.* nearly fix times lefs than an equal weight of iron.

"Laftly, by this method of examining precipitates, it may perhaps be poffible to determine the unequal quantities of phlogifton in different metals; for a given

258 Metals contain different quantities of phlogifton. weight of precipitating metal does not yield an equal quantity of precipitate: thus, for inftance, copper is able to precipitate from nitrous acid four times its weight of filver."

259 Table of different precipitates.

100 parts of	Precipitated by	Yielded dry precip.
Gold,	aerated mineral alkali -	106
———	cauftic - -	110
———	phlogifticated -	—
———	martial vitriol -	100
Platina,	aerated mineral alkali -	34
———	cauftic - -	36
———	phlogifticated -	—
Silver,	aerated mineral alkali -	129
———	cauftic - -	112
———	phlogifticated -	145
———	falited - -	133
———	vitriolated -	134
Mercury,	aerated mineral alkali -	110
———	cauftic - -	104
———	phlogifticated -	—
———	vitriolated - -	119
Lead,	aerated mineral alkali -	132
———	cauftic - -	116
———	phlogifticated -	—
———	vitriolated. - -	143
Copper,	aerated mineral alkali -	194
———	cauftic - -	158
———	phlogifticated -	530
Iron,	aerated mineral alkali -	225
———	cauftic - -	170
———	phlogifticated -	590
Tin,	aerated mineral alkali -	131
———	cauftic - -	130
———	phlogifticated -	250
Bifmuth,	aerated mineral alkali -	130
———	cauftic - -	125
———	phlogifticated -	180
———	pure water -	113
Nickel,	aerated mineral alkali -	135
———	cauftic - -	128
———	phlogifticated -	250
Arfenic,	aerated mineral alkali -	—

Arfenic,

Solution and Precipitation.

100 parts of	Precipitated by	Yielded dry precip.
Arſenic,	cauſtic	—
	phlogiſticated	180
	aerated mineral alkali	160
Cobalt,	cauſtic	140
	phlogiſticated	142
	aerated mineral alkali	193
Zinc,	cauſtic	161
	phlogiſticated	495
	aerated mineral alkali	140
Antimony	cauſtic	138
	phlogiſticated	138
	aerated mineral alkali	180
Mang.	cauſtic	168
	phlogiſticated	150

260
Kirwan's definition of chemical attraction.

Mr Kirwan has made a great number of experiments on the attractive powers of the mineral acids to various ſubſtances, and greatly illuſtrated the operations of both ſolution and precipitation. Chemical attraction, he obſerves, "is that power by which the inviſible particles of different bodies intermix and unite with each other ſo intimately, as to be inſeparable by mere mechanical means." Thus it differs from the attraction of coheſion, as well as from that of magnetiſm and electricity, as not acting with the indifference obſerved to take place in theſe powers, but cauſing a body already united to another to quit that and unite with a third; whence it is called *elective* attraction.

261
Difference betwixt chemical attraction and that of coheſion.

Hence attraction of coheſion often takes place betwixt bodies that have no chemical attraction for each other; as for inſtance, biſmuth and regulus of cobalt, which cannot be made to unite together by fuſion, though they cohere with each other ſo ſtrongly, that they cannot be ſeparated but by the blow of a hammer.

262
Geoffroy's rule for determining the degree of chemical attraction.

To determine the degrees of attraction betwixt different ſubſtances, M. Geoffroy laid it down as a general rule, that when two ſubſtances are united, and either quits the other to unite with a third, that which thus unites to the third muſt be ſaid to have a greater affinity to it than to the ſubſtance it has quitted.

263
Chemical decompoſitions, tho' ſeemingly ſingle are often double.

In many caſes, however, the ſeemingly ſingle decompoſition is in truth a double one. Thus, when the vitriolic acid expels the air from a fixed alkali, it does not neceſſarily follow, that the acid is more attracted by the alkali than the fixed air; for here though the latter reſigns its place to the acid, yet the acid gives out its fire to the air; whence a decompoſition might take place, even though the attractive powers of both the vitriolic and aerial acid to the alkali were equal.

264
Force of the attractive powers to be determined by numbers.

To attain to any certainty in this matter, therefore, it is neceſſary to determine the quantity and force of each of the attractive powers, and denote it by numbers. The neceſſity of this has been obſerved by Mr Morveau and Mr Wenzel, who have both propoſed methods for anſwering the purpoſe; but Mr Kirwan has ſhowed that both are defective: and he tells us,

265
True method of inveſtigating the quantity of attraction each of the acids has for its different baſes.

that the diſcovery of the quantity of real acid in each of the mineral acid liquors, with the proportion of real acid taken up by a given quantity of each baſis at the point of ſaturation, led him unexpectedly to what ſeems the true method of inveſtigating the quantity of attraction which each acid bears to the ſeveral baſes to which it is capable of uniting: "for it was impoſſible (ſays he) not to perceive, 1. That the quantity of real acid neceſſary to ſaturate a given weight of each baſis is inverſely as the affinity of each baſis to ſuch acid. 2. That the quantity of each baſis requiſite to ſaturate a given quantity of each acid is directly as the affinity of ſuch acid to each baſis. Thus 100 grains of each of the acids require for their ſaturation a greater quantity of fixed alkali than of calcareous earths, more of this earth than of volatile alkali, more of this alkali than of magneſia, and more of magneſia than of earth of alum.

"If an acid be united to leſs of any baſis than is requiſite for its ſaturation, its affinity to the deficient part of its baſis is as the ratio which that deficient part bears to the whole of what the acid can ſaturate. Thus, if 100 grains of vitriolic acid, which can ſaturate 110 of calcareous earth, be united only to 55, its affinity to the deficient 55 parts ſhould be eſtimated one half of its whole affinity; but its affinity to the retained part is as its whole affinity."

266
Method of explaining the decompoſitions effected by acids alone.

To explain the decompoſitions in which theſe acids are concerned, we muſt conſider, firſt, the powers which reſiſt any decompoſition, and tend to keep the bodies in their preſent ſtate; and, ſecondly, the powers which tend to effect a decompoſition and new union; the former our author calls *quieſcent affinities*, the latter *divellent*.

267
Quieſcent and divellent affinities.

A decompoſition will therefore always take place when the ſum of the divellent affinities is greater than the quieſcent; and, on the contrary, no decompoſition will happen when the ſum of the quieſcent affinities is greater than that of the divellent. All we have to do therefore is to compare the ſums of each of theſe powers. The method our author takes to compare the affinities together is by the following table; in which the quantity of alkali, earth, &c. ſaturated by 100 grains of each of the mineral acids, is ſtated.

268
Quantity of acid taken up by various baſes.

	Veg. fixed alkali.	Mineral alkali.	Calcar. earth.	Vol. alk.	Magneſia.	Earth of alum.
Vitriolic acid	215	165	110	90	80	75
Nitrous acid	215	165	96	87	75	65
Marine acid	215	158	89	79	71	55

Theſe numbers he conſiders as adequate expreſſions of the quanity of each of the affinities. Thus the affinity of the vitriolic acid to fixed vegetable alkali is to the affinity with which it adheres to calcareous earth as 215 to 110; and to that which the nitrous acid bears to calcareous earth as 215 to 96, &c.

269
Expreſſive of the quantity of attraction they have for each of theſe baſes.

Hence we ſum up the powers of affinity betwixt any number of different ſubſtances, and account for their decompoſitions, as in the following example of the double decompoſition, which takes place when a ſolution of vitriolated tartar and ſolution of lime or chalk in nitrous acid are mixed together.

270
Decompoſition of vitriolated tartar by ſolution of calcareous earth explained.

Quieſcent Affinities.		*Divellent Affinities.*	
Vitriolic acid to vegetable fixed alkali,	215	Vitriolic acid to calcareous earth,	110
Nitrous acid to calcareous earth,	96	Nitrous acid to vegetable alkali,	215
Sum of quieſcent affinities	311	Sum of divellent affinities	325

Hence we ſee that a double decompoſition muſt enſue. The ſame will be produced, if inſtead of vitriolated tartar we make uſe of Glauber's ſalt; for the ſum of the

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the quiescent affinities is 261, of the divellent 275; with vitriolic ammoniac the sum of the quiescent is 186, of the divellent 195, &c. In mixing vitriolated tartar with solution of magnesia in nitrous or marine acids, a double decomposition takes place though invisibly, as the vitriolic Epsom salt is very soluble in water, and therefore cannot be precipitated like selenite. In the former case the sum of the quiescent powers is 290, of the divellent 295; in the second 286 and 295.

271
Coincidence of the above table with experience.

Other decompositions take place in the same manner; and from all the facts which our author had occasion to observe, he concludes, that the quantity of each affinity, as determined in the above table, coincides exactly with experience; and that these decompositions are perfectly consistent with the superior affinity which has been hitherto observed in the vitriolic and nitrous acids with fixed alkalies over the calcareous earths; nor do they infringe in the least the known laws of affinity, as has been insinuated by some chemists.

272
Mistake of Dr Crell corrected.

One fact only, mentioned in Dr Crell's Journal, seems to be repugnant to what is here advanced; and that is, that if solutions of one part of alum and two of common salt be mixed together, evaporated, and set to crystallize, a Glauber's salt will be formed; though, in this case, the sum of the quiescent affinities is 233, and that of the divellent only 223. Mr Kirwan repeated this experiment without success; and Dr Crell himself owns that it will not succeed but in the most intense cold. If it does succeed at all, he says the decomposition must arise from a large excess of acid in the alum, which acted upon and decomposed the common salt: and this explanation is confirmed by the small proportion of Glauber's salt said to be obtained by this process; for from 30lb. of common salt and 16 of alum, only 15lb. of Glauber's salt were produced; whereas, if the whole of the alum had been decomposed, there should have been formed, according to Mr Kirwan's computation of the quantity of acid in the different salts, 29½lb, or, according to Mr Bergman's, 22lb. of Glauber's salt.

273
Formation of triple and quadruple salts.

In some cases, the neutral salts have a power of uniting, without any decomposition, or with only a very small one, to a third substance; thus forming triple salts, and sometimes quadruple; which often causes anomalies that have not yet been sufficiently investigated.

274
Volatile alkalies particularly form salts of this kind.

Volatile alkalies in particular are possessed of the power of uniting with neutral salts in this manner. Hence they seem to precipitate magnesia from Epsom salt, even when perfectly caustic; but this is owing to their combination with that salt, and forming a triple one, which is insoluble in water.

275
Vitriolic salts decomposed by the nitrous and marine acids.

It seems extraordinary that, according to Mr Kirwan's table, the three mineral acids should have the same affinity to vegetable fixed alkalies, when it is well known that the vitriolic will expel either of the other two from an alkaline basis. In explication of this, Mr Kirwan observes, that nitre is decomposed by the marine acid; and that Glauber's salt and vitriolic ammoniac are decomposed by that of nitre; and that these salts, as well as cubic nitre and nitrous ammoniac, are decomposed by the marine acid.

276
These decompositions supposed to arise from compound forces.

Mr Kirwan is of opinion, that these decompositions are the effect of a double affinity, or at least of compound forces. He suspected that they arose from the different capacities of the acids for elementary fire; and to determine this matter, he made the following experiments, in which the decompositions were not discovered by crystallization, but by tests.

277
Experiments to determine this by the various degrees of heat excited by mixtures.

1. Having procured a quantity of each of the three mineral acids containing the same proportion of real acid, and reduced them to the temperature of 68° of Fahrenheit, 100 grains of vitriolic acid, containing 26.6 of real acid, was projected upon 480 grains of oil of tartar at the same temperature, by which the thermometer was raised to 138°.

2. An hundred grains of spirit of nitre, containing also 26.6, projected on 480 grains of oil of tartar, produced only 120° of heat.

3. An hundred grains of spirit of salt, the specific gravity of which was 1220, and which contained the usual proportion of real acid, raised the thermometer from 69 to 129.

278
Vitriolic acid contains more fire than the nitrous and marine.

"Hence (says he) it follows, that the vitriolic acid contains more specific fire, or at least gives out more by uniting with fixed alkalies, than either the nitrous or marine; and therefore when the vitriolic acid comes in contact with either nitre or salt of Sylvius, its fire passes into these acids, which are thereby rarefied to a great degree, and are thus expelled from their alkaline basis, which is then seized on by the vitriolic."—

279
Difficulty in the theory.

On this, however, it is obvious to remark, that, according to Mr Kirwan's explanation, the marine acid, as giving out more specific heat, ought to expel the nitrous from an alkaline basis; which, however, is not the case. Something else, therefore, besides the mere quantity of specific heat, must here be taken into consideration. Mr Kirwan, however, goes on to prove the truth of his theory by the following experiments.

280
On the expulsion of the nitrous acid by the vitriolic diluted.

4. To 400 grains of vitriolic acid, whose specific gravity was 1.362, sixty grains of nitre were added; on which the thermometer fell from 68° to 60°. During the time of this descent, the nitrous acid was not expelled; for some filings of copper, put into the mixture, were not acted upon in the least; but in five minutes afterwards they visibly effervesced, which showed that the nitrous acid began to be expelled; for the vitriolic acid does not act upon copper but by a boiling heat.

281
By the same acid concentrated.

5. Sixty grains of nitre were put to 400 of oil of vitriol, whose specific gravity was 1.870; the thermometer instantly rose from 68° to 105°, and the nitrous acid was expelled in a visible fume.—"These experiments (says Mr Kirwan) prove, 1. That neutral salts are not decomposed by mere solution in an acid different from their own. 2. That the nitrous acid, being converted into vapour, had imbibed a large quantity of fire.

282
With a small quantity of diluted vitriolic acid.

But as the vitriolic acid, in both these experiments, was used in much larger quantity than was necessary to saturate the alkali of the nitre, sixty grains of the latter were put into 64 of the abovementioned dilute spirit of vitriol, which contained the same quantity of real vitriolic acid that the 60 grains of nitre did of the nitrous; with the addition of 40 grains of water and a few copper-filings. In less than two hours the copper was acted upon, and consequently the nitrous acid was expelled.

283
On the expulsion of marine acid by the concentrated vitriolic.

6. To 400 grains of oil of vitriol, of the specific gravity of 1.870, 100 grains of common salt were added. An effervescence immediately ensued,

and the marine acid rose in white vapours. A thermometer held in the liquor rose only 4 degrees, but in the froth it ascended to 10°, and fell again upon being replaced in the liquor.

284
Both the nitrous and marine acids receive fire from the vitriolic during their expulsion.

Hence Mr Kirwan concludes, that the vitriolic acid gives out its fire to the marine; and that this latter received more than it could absorb even in the state of vapour, and therefore communicated heat to the contiguous liquor. It appears to him also, that the nitrous and marine acids receive fire from the vitriolic, and are thrown into a vaporous state, or at least rarefied to such a degree as to be expelled from their alkaline basis, though their affinity with that basis may be equally strong with the vitriolic.

285
On the decomposition of vitriolated tartar by nitrous acid.

7. To ascertain the manner in which vitriolated tartar and Glauber's salt are decomposed by spirit of nitre, 60 grains of powdered tartar of vitriol were put into 400 of nitrous acid, whose specific gravity was 1.355, and which contained about 105 grains of real acid. The thermometer was not affected by the mixture; but in 24 hours the vitriolic acid was in part disengaged, as appeared by the acid mixture acting upon regulus of antimony, which neither pure vitriolic nor pure nitrous acid will do by themselves. On putting the same quantity of vitriolated tartar into 400 grains of spirit of nitre whose specific gravity was 1.478°, the thermometer rose from 67° to 79°: the vitriolated tartar was quickly dissolved, and the regulus of antimony showed that the vitriolic acid, was disengaged.

286
Acids unite to alkalies by giving out fire, and quit them by receiving it.

Hence it appeared that the nitrous acid, having the same affinity with the basis of vitriolated tartar as the vitriolic, but giving out, during the solution, more fire than was necessary to perform the solution, the vitriolic, receiving this fire, was disengaged: for as it cannot unite to alkalies without giving out fire; so when it receives back that fire, it must quit them. The reason why the nitrous acid, which specifically contains less fire than the vitriolic, gives out so much is, that its quantity in both these experiments is far greater than that of the vitriolic; it being in the first as 105 to 17, and in the last as 158 to 17.

287
Vitriolated tartar cannot be decomposed by diluted nitrous acid.

8. To 60 grains of spirit of nitre, whose specific gravity was 1.355, Mr Kirwan added 1000 grains of water; and into this dilute acid put 60 grains of vitriolated tartar, containing exactly the same quantity of real acid that the 60 grains of nitrous acid did. In eight days the vitriolated tartar was almost entirely dissolved, and without any sign of its decomposition; and no nitre was found upon evaporating the liquor. Hence he concludes, that the nitrous acid can never decompose vitriolated tartar, without the assistance of heat, but when its quantity is so great that it contains considerably more fire, and by the act of solution is determined to give out this fire. This salt is also decomposed, in similar circumstances, by the marine acid; though still more slowly and with more difficulty than by the nitrous, as appears by the following experiments.

288
Decomposition of vitriolated tartar by marine acid.

9. Into 400 grains of spirit of salt, whose specific gravity was 1.220, were put 60 grains of vitriolated tartar. The thermometer was not affected in the least, and the salt dissolved very slowly. Some pulverized bismuth was added to try whether the vitriolic acid was disengaged; and in 12 hours part of it was dissolved, so that it could not be precipitated by water. This showed, that part of the vitriolic acid was dislodged; for this semi-metal cannot be kept in solution when much diluted with water, excepting by a mixture of marine and vitriolic acids.

289
Requisites for the success of this experiment.

In this experiment the quantity of marine acid was much greater than that of the vitriolic; and therefore it was capable of dislodging it. This circumstance alone, however, is not sufficient; the acid must be disposed to give out by solution that quantity of fire which it is necessary the vitriolic should receive in order to its quitting the basis to which it is united; and

290
Vitriolated tartar dissolved in water cannot be decomposed by marine acid, and why.

therefore when Mr Cornette added two ounces of spirit of salt to half an ounce of vitriolated tartar already dissolved, in water, no decomposition took place. The reason of this was, that as the vitriolated tartar was already dissolved, no cold nor heat was generated by the mixture; and therefore the spirit of salt could not give out any fire. Glauber's salt is more easily decomposed by marine acid then vitriolated tartar, on account of its being more easily soluble in spirit of salt; and likewise because its alkaline basis takes up an equal quantity of both acids: consequently the marine gives out more fire in uniting to the basis of Glauber's salt than on being united to that of vitriolated tartar.

291
Decomposition of vitriolic ammoniac and Glauber's salt by marine acid never complete.

Vitriolic ammoniac is also decomposed by means of marine acid; but in all these cases, the quantity of marine acid must greatly exceed that of the vitriolic contained in the salt to be decomposed; and it must be remarked, that according to the observations of Mr Bergman, the decomposition of Glauber's salt or vitriolic ammoniac by this acid is never complete.

292
Nitrous salts decomposed by marine acid.

On the same principles the marine acid decomposes salts which have the nitrous acid for their basis. Mr Cornette found, that cubic nitre was more easily decomposed by it than that which has vegetable alkali for its basis. Accordingly, during the solution of prismatic nitre, only three degrees of cold were produced; but six by the solution of cubic nitre; which shows that the spirit of salt gave out more fire in the latter case than in the former; and its quantity must always be greater than that of the nitrous acid contained in the mineral alkaline basis; because this basis requires for its saturation more of the marine than of the nitrous acid. The nitrous acid, however, in its turn decomposes salt of Sylvius and common salt; but it must always be in greater quantity than the marine to produce that effect.

293
Marine salts decomposed by the nitrous acid.

10. Sixty grains of common salt being added to 400 of colourless spirit of nitre, whose specific gravity was 1.478, the mixture quickly effervesced and grew red, yet the thermometer rose but two degrees; which showed that the marine acid had absorbed the greater part of the first given out by that of nitre; the decomposition was likewise hastened by the superior affinity of the nitrous acid to the alkaline basis of the sea-salt: hence the decomposition of sea-salt by means of nitre takes place without any solution; but spirit of salt will not decompose cubic nitre until it has first dissolved it. This mutual expulsion of the nitrous and marine acids by each other, is the reason why aqua-regia may be made by adding nitre or nitrous ammoniac to spirit of salt, as well as by adding common salt or sal ammoniac to spirit of nitre.

Selenite cannot be decomposed either by nitrous or

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marine acid; becauſe it cannot be diſſolved in either without the aſſiſtance of foreign heat. It muſt likewiſe be obſerved, that in all decompoſitions of this

294 Selenites cannot be decompoſed by marine acid.

kind, when the liquor has been evaporated to a certain degree, the vitriolic acid expels in its turn the nitrous or marine acid to which it had already yielded its baſis. The reaſon of this is, that the free part of the weaker acids being evaporated, the neutral ſalts begin to cryſtallize, and then giving out heat, the vitriolic abſorbs it; and thus reacting upon them expels them from the alkali or earth to which they are united.

295 Why the vitriolic acid aſſumes on evaporation the baſes it had loſt.

Mr Kirwan found much more difficulty in determining the attractive powers of the different acids to the metals than to alkaline ſalts or earths. Some of the difficulties met with in this caſe aroſe from the nature of metallic ſubſtances themſelves. Their calces when formed by fire always contain a quantity of air, which cannot be extracted from them without great difficulty, and is very ſoon re-abſorbed; and if formed by ſolution, they as conſtantly retain a part of their ſolvent or precipitant; ſo that the preciſe weight of the metalline part can ſcarce be diſcovered. Our author, therefore, and becauſe metallic calces are generally inſoluble in acids, choſe to have the metals in their perfect ſtate: and even here they muſt loſe a part of their phlogiſton before they can be diſſolved in acids, and a conſiderable part remains in the ſolution of the acid and calx; which laſt quantity he endeavoured to determine.

296 Difficulties in determining the attractive powers of the acids to metals.

297 Metallic ſalts inſoluble in water without an exceſs of acids.

A new difficulty now occurred, ariſing from the impoſſibility of finding the real quantity of acid neceſſary to ſaturate the metal, for all metallic ſolutions contain an exceſs of acid: the reaſon of which is, that the ſalts formed by a due proportion of acid and calx are inſoluble in water without a further quantity of acid; and in ſome caſes this quantity, and even its proportion to the aqueous part of the liquor, muſt be very conſiderable, as in ſolutions of biſmuth. It was in vain attempted to deprive thoſe ſolutions of their exceſs of acid by means of cauſtic alkalies and lime-water; for when deprived of only part of it, many of the metals were precipitated, and all of them would be ſo if deprived of the whole. As the ſolution of ſilver, however, can be very much ſaturated, Mr Kirwan began with it and found that 657 grains of this ſolution contained 100 grains of ſilver, and 31.38 grains of real acid, after making the proper allowance for the quantity diſſipated in nitrous air. Nine grains of this ſolution tinged an equal quantity of ſolution of litmus as red as $\frac{8}{10}$ of a grain of real acid of ſpirit of nitre would have done; whence our author concluded that 9 grains of his ſolution of ſilver contained an exceſs of $\frac{8}{10}$ of a grain of real ſilver: according to which calculation, the whole quantity ought to have contained 5.6 grains; which deducted from 31.38, leaves 25.78 grains for the quantity of acid ſaturated by 100 grains of ſilver.

As the vitriolic ſolutions of tin, biſmuth, regulus of antimony, nickel, and regulus of arſenic, contain a large exceſs of acid, Mr Kirwan ſaturated part of it with cauſtic volatile alkali before he tried them with the infuſion of litmus; and the ſame method was uſed with ſolutions of iron, lead, tin, and regulus of antimony in the nitrous and marine acids. The proportion of vitriolic and marine acid taken up by lead, ſilver, and mercury, were determined by computing the quantity of real acid neceſſary to precipitate theſe metals from their ſolutions in the nitrous acid; which ſeemed to be the moſt exact method of determining this point. The reſult of all the experiments was, that 100 grains of each of theſe acids take up at the point of ſaturation of each metallic ſubſtance, dephlogiſticated ſuch a degree as is neceſſary for its ſolution in each acid, the quantities marked in the following table.

298 Quantities of the different metals taken up by acid.

100 grains of	Iron.	Copper.	Tin.	Lead.	Silver.	Merc.	Zinc.	Biſmuth.	Nickel.	Cobalt.	Reg. of ant.	Reg. of arſen.
Vitriolic acid	270	260	138	412	390	432	318	250 310	320	360	200	260
Nitrous acid	255	255	120	365	375	416	304	290	300	350	194	220
Marine acid	265	265	130	400	420	438	312	250 320	275 310	370	198	290

Though from this table, compared with the former, we might ſuppoſe that metals, having a greater attraction for acids than alkalies, could not be precipitated by them, yet Mr Kirwan obſerves, that the common tables, which poſtpone metallic ſubſtances to alkaline ſalts, are in reality juſt, though there can ſcarce be any room to doubt that almoſt all metallic ſubſtances have a greater affinity with acids than alkalies have. The common tables, he ſays, are tables of precipitation rather than of affinity, as far as they relate to metallic ſubſtances. Theſe precipitations, however, are conſtantly the reſult of a double affinity and decompoſition; the precipitating metal yielding its phlogiſton to the precipitated one, while the precipitated metal yields its acid to the other. Thus, though copper in its metallic form precipitates ſilver and mercury from the nitrous acid, yet the calx will precipitate neither.

299 Metals have a greater affinity with acids than alkalies.

300 Why alkalies precipitate the metals.

The ſuperior attraction the nitrous acid has to ſilver rather than fixed alkali, appears from the following experiment. If a ſolution of ſilver in nitrous acid be poured into a mixed ſolution of alkali and ſea-ſalt, the ſilver will be precipitated by the ſea-ſalt into a luna cornea, and not by the looſe alkali contained in the liquor. "Now (ſays Mr Kirwan), if the nitrous acid had a greater affinity to the free alkali than to the ſilver, it is evident that the ſilver would be precipitated pure, and not in the ſtate of luna cornea; but from its being precipitated in this ſtate, it is plain, that the precipitation was not accompliſhed by a ſingle but by a double affinity. Hence alſo the marine acid appears to have a greater attraction to ſilver than the nitrous has to fixed alkalies. The reſult is ſimilar when we make uſe of ſolutions of lead or mercury in the nitrous acid. Mr Bayen has alſo ſhown, that vitriol of lead and corroſive ſublimate mercury cannot be deprived of more than half their acid, even by cauſtic fixed alkalies.

301 Nitrous acid attracts ſilver more than fixed alkali.

Solution and Precipitation.

With regard to lead, if perfectly dry salt be projected on this metal heated to ignition, the common salt will be decomposed, and plumbum corneum formed. Nor

302
Sea-salt decomposed in various ways by means of lead.

can we attribute this to the volatilization of the alkali by heat; for the alkali is as fixed as the lead, and must therefore be caused by the superior attraction which the calx of this metal, even when dephlogisticated, has for the marine acid. Mr Scheele informs us, that if a solution of common salt be digested with litharge, the common salt will be decomposed, and a caustic alkali produced. It may also be decomposed simply by letting its solution pass slowly through a funnel filled with litharge; and the same thing happens to a solution of calcareous earth in marine acid; which shows that the decomposition takes place merely by the superior degree of attraction betwixt the acid and metallic calx (A).

303
Acids attract metallic earth more strongly than volatile alkali.

That acids have a greater attraction for metallic earths than volatile alkalies, is still more evident. Luna cornea is soluble in volatile alkalies; but if this solution be triturated with four times its weight of quicksilver, a *mercurius dulcis*, and not sal ammoniac, is formed. The reason why alkalies and earths precipitate all metallic solutions is, that the metals are held in solution by an excess of acid. Even if the alkaline and earthy substance did no more than absorb this excess of acid, a precipitation must necessarily ensue; but they not only take up this superabundant acid, but also the greater part of that which is necessary to saturate the metallic earth. This they are enabled to do by means of a double affinity; for during the solution of metals, only a small part of the phlogiston, comparatively speaking, escapes, the remainder being retained by the compound of acid and calx. When therefore an alkali or earth is added to such a solution, the phlogiston quits the acid, and joins with the calx, while the greater part of the acid reunites to the precipitate. Notwithstanding this great

304
Why the metallic earths seldom decompose salts having an earth or alkali for their basis.

affinity, however, of metallic earths to acids, there are but few instances of their decomposing those salts which have an alkali, or an earth for their basis, by reason of the inability of the acids, while combined with these bases, and thereby deprived of a great part of their specific fire, to volatilize the phlogiston combined with the metallic earths, which must necessarily be expelled before an acid can combine with them: and as to the metallic calces, they are generally combined with fixed air, which must also be partly expelled; but ammoniacal salts (containing much more fire, for they absorb it during their formation) for that reason act much more powerfully on metals. Allowing then the affinities of the mineral acids with metallic substances to be as above, all double decompositions, in which only salts containing these acids united to alkaline, terrene, or

305
Decomposition of vitriolated tartar by solution of silver explained;

metallic bases, are concerned, admit of an easy explanation; nay, says Mr Kirwan, I am bold to say, they cannot otherwise be explained. Thus, if a solution of tartar vitriolate, and of silver in the nitrous acid, be mixed in proper proportion, nitre and vitriol of silver will be formed; and this latter for the most part precipitated.

Quiescent Affinities		*Divellent Affinities.*	
Nitrous acid to silver,	375	Nitrous acid to vegetable alkali,	215
Vitriolic acid to vegetable alkali,	215	Vitriolic acid to silver,	390
	590		605

306
And of Glauber's salt, vitriolic ammoniac, &c.

Thus also, if, instead of a solution of tartar vitriolate, that of Glauber's salt, or of vitriolic sal ammoniac, selenite, Epsom salt, or alum, be used, the balance is constantly in favour of the divellent powers; and a precipitation is the consequence, though but slight when selenite or alum are used.

307
In what cases solution of silver is precipitated by other metals.

Solution of silver is also precipitated by the vitriolic solutions of iron, copper, tin, and probably by many other solutions of metals in the vitriolic acid: for this reason, among others undoubtedly, that they contain an excess of acid: but if a saturated solution of silver be mixed with a very saturated solution of lead or mercury in the vitriolic acid, the silver will not be precipitated; and in both cases the balance is in favour of the quiescent affinities.

308
Constantly decomposed by marine salts;

All the marine neutral salts, whether the basis be alkaline, terrene, or metallic, decompose the nitrous solution of silver; and these decompositions are constantly indicated by the balance of affinities already described. The same thing also takes place with solution of silver in the vitriolic acid, as is indicated also by the same

309
As also solution of lead.

table. The nitrous solution of lead is also decomposed, and the metal for the most part precipitated, unless the solution be very dilute in the form of vitriol of lead, by all the neutral salts containing either the vitriolic or marine acid, excepting only the combination of silver with marine acid, which precipitates it in no other way than by its excess of acid.

310
Solution of lead in marine acid decomposed by vitriolic salts;

Solution of lead in marine acid is decomposed by all the neutral salts containing the vitriolic acid, excepting only selenite and solution of nickel in oil of vitriol. These can only precipitate it by virtue of an excess of acid.

Nitrous solution of mercury is decomposed by all the neutral salts containing the vitriolic acid, except vitriol of lead, which only decomposes it by an excess of acid.

311
Also nitrous solutions of mercury;

All the salts containing marine acid decompose the nitrous solution of mercury, excepting the combinations of marine acid with silver and lead, which decompose it by excess of acid.

312
And by the salts containing marine acid.

These salts also decompose vitriol of mercury, tho' a precipitation does not always appear, owing, as Mr Kirwan supposes, to the facility with which a small quantity of the marine salt of mercury is soluble in an excess of acid. Marine salt of silver, however, decomposes vitriol of mercury only through its excess of acid. Hence we

313
Vitriol of mercury decomposed by marine acid.

see why luna cornea can never be reduced by fixed alkalies without loss; and were it not that the action of the alkali is assisted by heat, it never could be reduced by them at all.

314
Why luna cornea cannot be reduced without loss by alkaline salts.

When oil of vitriol is mixed with a solution of corrosive sublimate, a precipitate falls; but this, as Mr Bergman remarks, does not proceed from a decompo- F 2 sition

(A) These experiments have been repeated by many other chemists without success; and Mr Wiegleb informs, that none of those who have attempted to decompose sea-salt by means of lead, ever found their methods answer the purpose.

ſition of the mercurial ſalt, but from an abſtraction of the water neceſſary to keep the ſublimate diſſolved.

315 Precipitation of corroſive mercury by oil of vitriol explained.

316 Table of the affinities to the different metals explained.

In the foregoing table two different affinities are aſſigned to the vitriolic acid with regard to biſmuth and nickel; one ſhowing the affinity which theſe acids bear to the metals when dephlogiſticated only by ſolution in the acids; the other that which the acids bear to them when more dephlogiſticated, as when they are diſſolved in the nitrous acid. On the other hand, all the acids have leſs affinity with the calces of iron, zinc, tin, and antimony, when they are dephlogiſticated to a certain degree; but our author found himſelf unable to give any certain criteria of this dephlogiſtication.

317 Of the quantity of phlogiſton contained in the different metals.

318 Method of calculating this quantity exemplified in regulus of arſenic.

The moſt difficult point to be ſettled was the precipitation of metals by each other from the mineral acids. To determine this it was neceſſary to find the quantity of phlogiſton in each of them, not only in their natural ſtate, but according to their various degrees of dephlogiſtication by each of the acids. The ſubſtance he choſe for determining the abſolute quantity of phlogiſton in a metallic ſubſtance was regulus of arſenic. An hundred grains of this ſemimetal diſſolved in dilute nitrous acid yielded 102.4 cubic inches of nitrous air; which, according to his calculations on that ſubject, contain 6.86 grains of phlogiſton: and hence he concluded that 100 grains of regulus of arſenic contain 6.86 grains of phlogiſton. From this experiment, three times repeated with the ſame ſucceſs, our author proceeded to form, by calculation, a table of the abſolute quantity of phlogiſton contained in metals, the relative quantity having been computed by Mr Bergman and his calculations adopted by our author. Theſe quantities are as follow.

319 Table of the quantities of phlogiſton in different metals.

		Relative Quantity.	Abſolute Quantity
100 grains	Gold	394	24.82
	Copper	312	19.65
	Cobalt	270	17.01
	Iron	233	14.67
	Zinc	182	11.46
	Nickel	156	9.82
	Regulus of antimony	120	7.56
	Tin	114	7.18
	Regulus of arſenic	109	6.86
	Silver	100	6.30
	Mercury	74	4.56
	Biſmuth	57	3.59
	Lead	43	2.70

320 Experiments explaining the reduction of ſilver *per ſe*.

This point he likewiſe endeavoured to aſcertain by other experiments. As ſilver loſes a certain quantity of phlogiſton, which eſcapes and ſeparates from it during its ſolution in nitrous acid, he concluded, that if the ſolution was expoſed to nothing from which it could reobtain phlogiſton, and this was diſtilled to dryneſs, and entirely ſeparated from the acid, as much ſilver ſhould remain unreduced as correſponded with the quantity of phlogiſton loſt by it; and if this quantity correſponded with that in the above table, he then had good reaſon to conclude that the table was juſt.

For this purpoſe 120 grains of ſtandard ſilver were diſſolved in dephlogiſticated nitrous acid diluted with water, and he obtained from it 24 cubic inches of nitrous air. This ſolution was gently evaporated to dryneſs; and he found that, during the evaporation, about a quarter of a grain of the ſilver had been volatilized. The dry reſiduum was then diſtilled, and kept an hour in a coated green-glaſs retort heated almoſt to a white heat. Abundance of nitrous acid paſſed off during the operation, and a green and white ſublimate roſe into the neck of the retort, ſome of it even paſſing over into the receiver. On breaking the retort, the inſide was penetrated with a yellow and red tinge, and partly covered over with an exceedingly fine ſilver powder, which could ſcarcely be ſcraped off. The remainder of the ſilver was white, and perfectly free from acid, but not melted into a button. On being collected, it weighed 94 grains; conſequently 26 grains had been loſt either by ſublimation or vitrification; but of theſe 26 grains 9 were copper; for 100 grains of ſtandard ſilver contain 7½ of copper, therefore only 17 grains of pure ſilver remained unreduced, being either volatilized or vitrified. The whole quantity of pure ſilver in 120 grains of ſtandard ſilver amounts to 111 grains; then if 111 grains of pure ſilver loſe 17 by being deprived of its phlogiſton, 100 grains of the ſame ſhould loſe 15.3; and by the above table 15.3 grains of ſilver ſhould contain 0.945 of a grain of phlogiſton. Now, 100 grains of pure ſilver afford 14 cubic inches of nitrous air, which, according to our author's calculation, contain 0.938 of a grain of phlogiſton; and this differs from 0.945 only by ,007 of a grain. "In this experiment (ſays Mr Kirwan) only as much of the ſilver ſublimed as could not regain phlogiſton; the remainder regained it from the nitrous air abſorbed by the ſolution, and by that which remained in the acid and calx. If this were not ſo, I do not ſee why the whole of the ſilver would not ſublime."

321 Quantity of pure metal contained in ſtandard ſilver.

322 Examination of Dr Prieſtley's experiment concerning the revival of mercury.

Dr Prieſtley having ſeveral times diſſolved mercury in the nitrous acid, and revivified it by diſtilling over that acid, conſtantly found a conſiderable portion of it unreduced. To try whether that proportion correſponded with his calculation, Mr Kirwan examined Dr Prieſtley's experiment, *viz.* that having diſſolved 17 penny-weights 13 grains (321 grains) of mercury in nitrous acid, 36 grains remained unreduced. According to Mr Kirwan's calculation 56 grains ſhould have remained unreduced; for 100 grains of mercury afford 12 cubic inches of nitrous air; of conſequence 321 grains ſhould afford 38.52, which contain 2.58 of phlogiſton: and if, as according to the table, 4.56 grains of phlogiſtion be neceſſary to metallize 100 grains of mercury, 2.58 grains will be neceſſary to metallize 56 grains of the ſame metal; and our author is ſatisfied from his own trials, that more than 50 grains would have remained unreduced, if dephlogiſticated nitrous acid had been uſed in diſſolving the mercury, and the ſolution performed with heat and a ſtrong acid: but that which the Doctor uſed was of the ſmoking kind, and conſequently contained a conſiderable quantity of phlogiſton already, which undoubtedly contributed to revive more of the metal than would otherwiſe have been done. It is true, Dr Prieſtley afterwards revived a great part of what had originally remained unreduced; but this happened after it had been ſome time expoſed to the free air, from which the calces of metals always attract phlogiſton; as is evident in luna cornea, which blackens on being expoſed to the air.

323 Why ſo much of the metal was revived in the Doctor's experiments.

By another experiment of Dr Prieſtley's, it was found

Solution and Precipitation.

324 Of the revival of lead from minium by inflammable air.

found, that nearly five pennyweights of minium, from whence all its air was extracted, that is, about 118 grains, abſorbed 40 ounce-meaſures, or 75.8 cubic inches of inflammable air, containing 2.65 grains of phlogiſton, by which they were reduced. An hundred grains of minium, therefore, require for their reduction nearly 2.25 grains of phlogiſton. In another experiment made with more care, he found, that 480 grains of minium abſorbed 108 ounce-meaſures of inflammable air; ſo that, according to this, 100 grains of minium require for their reduction 1.49 grains of phlogiſton; and in two ſucceeding experiments he found the quantity ſtill leſs.

325 Mr Kirwan's remarks on the experiments of Dr Prieſtley.

On this Mr Kirwan remarks, 1. That the whole of the minium was not dephlogiſticated; for it is never equally calcined, and beſides much of it muſt have been reduced during the expulſion of its air. 2. The quantity of phlogiſton in the inflammable air may have been greater, as this varies with its temperature and the weight of the atmoſphere: ſo that on the whole theſe experiments confirm the reſults expreſſed in the table.

326 Of the attraction of metallic calces to phlogiſton.

Mr Kirwan next proceeds to conſider the attraction of metallic calces to phlogiſton. Inflammable air, when condenſed into a ſolid ſubſtance, he ſuppoſes not only equal, but much ſuperior, to any metallic calx in ſpecific gravity; and therefore, if we could find the ſpecific gravity of any calx free both from phlogiſton and fixed air, we would thus know the denſity which phlogiſton acquires by its union with ſuch calx.

327 Of finding the ſpecific gravity of the different metallic calces.

It has, however, hitherto proved impoſſible to procure calces in ſuch a ſtate; as, during their dephlogiſtication, they combine with fixed air or ſome particles of the menſtruum, whence their abſolute weight is increaſed, and their ſpecific gravity diminiſhed. Hence it appears, that the ſpecific gravity of the calces differs much leſs from that of their reſpective metals, than the ſpecific gravity which the phlogiſton acquires by its union with thoſe calces from that which it poſſeſſes in its uncombined ſtate. Hence, inſtead of deducing the quantity of affinity betwixt phlogiſton and metallic calces from the following propoſition, that "the affinity of metallic calces to phlogiſton is in a compound ratio of its quantity and denſity in each metal," he is obliged

328 Whence their various degrees of affinity to phlogiſton may be determined.

to deduce it from this other, that "the affinity of metallic calces to phlogiſton is directly as the ſpecific gravity of the reſpective metals, and inverſely as the quantity of calx contained in a given weight of theſe metals." This latter propoſition is an approximation to the former, founded on this truth, that "the larger the quantity of phlogiſton in any metal is, the ſmaller is the quantity of calx in a given weight of that metal;" and, that "the denſity which the phlogiſton acquires is as the ſpecific gravity of the metal." This latter propoſition, however, is not ſtrictly true, for this denſity is much greater; but its defect is only ſenſible with regard to thoſe metals which contain a conſiderable quantity of phlogiſton, as gold, copper, cobalt, and iron. With regard to the reſt, it is of no importance. The ſpecific gravity of the different metals, then, being as repreſented in the firſt column of the following table, the affinity of their calces to phlogiſton will be as in the ſecond; and the third expreſſes the affinities in numbers homogeneous with thoſe which expreſs the affinities of acids with their baſis.

330 Table of the proportional affinities of metallic calces to phlogiſton.

	Specific Gravity.	Proportionable Affinities.	Real Affinities of Calx to Phlogiſt.
Gold	19	0.25	1041
Mercury	14	0.147	612
Silver	11.091	0.118	491
Lead	11.33	0.116	483
Copper	8.8	0.109	454
Biſmuth	9.6	0.099	412
Cobalt	7.7	0.092	383
Iron	7.7	0.090	375
Regulus of Arſenic	8.31	0.089	370
Zinc	7.24	0.0812	338
Tin	7	0.075	312
Regulus of Antimony	6.86	0.074	308

331 Why lead is uſeful in cupellation.

From this table we may ſee why lead is uſeful in cupellation; namely, becauſe it has a greater affinity with phlogiſton than the calces of any of the other imperfect metals; conſequently after it has loſt its own phlogiſton, it attracts that of the other metals with which it is mixed, and thus promotes their calcination and vitrification.

332 Quantity of phlogiſton loſt by metals during calcination.

The third point neceſſary for the explanation of the phenomena attending the ſolution of metals, and their precipitation by each other, is to determine the proportion of phlogiſton which they loſe by ſolution in each of the acids, and the affinity which their calces bear to the part ſo loſt. Though our author was not able to determine this by any direct experiment, yet from various conſiderations he was led to believe that it was as follows:

Quantity of Phlogiſton ſeparated

	Iron	Copper	Tin	Lead	Silver	Mercury	Zinc	Biſmuth	Cobalt	Nickel	Reg. of Ant.	Reg. of Arſ.
By the vitriolic acid	$\frac{2}{3}$	$\frac{8}{10}$	$\frac{7}{10}$	$\frac{93}{100}$	Entire	$\frac{87}{100}$	$\frac{85}{100}$	$\frac{85}{100}$	$\frac{93}{100}$	Entire	$\frac{97}{100}$	$\frac{86}{100}$
By nitrous acid	$\frac{6}{7}$	$\frac{84}{100}$	$\frac{7}{10}$	$\frac{88}{100}$	Entire	$\frac{9}{10}$	$\frac{99}{100}$	$\frac{97}{100}$	Entire	Entire	Entire	$\frac{99}{100}$
By marine acid	$\frac{48}{100}$	$\frac{67}{100}$	$\frac{3}{10}$	$\frac{6}{10}$	——	——	$\frac{6}{10}$	$\frac{7}{10}$	$\frac{94}{100}$	$\frac{8}{10}$	$\frac{84}{100}$	$\frac{8}{10}$

329 Of the affinity of calces to the deficient part of their phlogiſton.

The affinity of the calces to the deficient part of their phlogiſton may now be eaſily calculated; for they may be conſidered as acids, whoſe affinity to the deficient part of their baſis is as the ratio which that part bears to the whole. Thus the affinity of iron, thoroughly deprived of its phlogiſton, being 375, as it loſes two-thirds of its phlogiſton by ſolution in the vitriolic acid, the affinity of iron to theſe is two-thirds of its whole affinity; that is, two-thirds of 375, or 250.

333 Uſe of theſe calculations and tables for knowing *à priori* the phenomena of precipitation.

Thus we may eaſily conſtruct a table of the affinities of the phlogiſton of different metals for their calces; and from this and that formerly given, by which the affinities of the acids to the metallic calces was expreſſed, we may gueſs what will happen on putting one metal in the ſolution of another. Thus if a piece of copper be put into a ſaturated ſolution of ſilver, the ſilver will be precipitated; for the balance is in favour of the divellent powers, as appears from the following calculation.

Quieſcent

Solution and Precipitation.

Quieſcent Affinities.		*Divellent Affinities.*	
Nitrous acid to ſilver	375	Nitrous acid to copper	255
Calx of copper to phlogiſton	363	Calx of ſilver to phlogiſton	491
Sum of the quieſcent affinities	738	Sum of the divellent	746

334 Of the exceſs of acid in ſolutions proper for making theſe experiments.

In making theſe experiments the ſolutions muſt be nearly, though not entirely, ſaturated. If much ſuperfluous acid be left, a large quantity of the added metal will be diſſolved, before any precipitation can be made to appear; and when the ſolution is perfectly ſaturated, the attraction of the calces for one another begins to appear; a power which ſometimes takes place, and which has not yet been fully inveſtigated.

335 Why the metals are more dephlogiſticated by mutual precipitation than by direct ſolution.

In this way the precipitating metals are more dephlogiſticated than by direct ſolution in their reſpective menſtrua; and are even diſſolved by menſtrua which would not otherwiſe affect them. The reaſon of this is, that their phlogiſton is acted upon by two powers inſtead of one: and hence, though copper be directly ſoluble in the vitriolic acid only when in its concentrated ſtate, and heated to a great degree; yet if a piece of copper be put into a ſolution of ſilver, mercury, or even iron, though dilute and cold, and expoſed to the air, it will be diſſolved; a circumſtance which has juſtly excited the admiration of ſeveral eminent chemiſts, and which is inexplicable on any other principles than thoſe juſt now laid down. From this circumſtance we may ſee the reaſon why vitriol of copper, when formed by nature, always contains iron.

336 Why copper is diſſolved by ſolution of ſilver, mercury, or iron.

Mr Kirwan now proceeds to conſider the ſolutions of metallic ſubſtances in all the different acids.

337 Iron and zinc the only metals diſſolved by vitriolic acid.

Vitriolic acid, he obſerves, diſſolves only iron and zinc of all the metallic ſubſtances, becauſe its affinity to their calces is greater than that which they bear to the phlogiſton they muſt loſe before they can unite with it.

338 Nitrous acid diſſolves all metals, though it has leſs affinity with them than the vitriolic or marine.

Nitrous acid has leſs affinity with all metallic ſubſtances than either the vitriolic or marine; yet it diſſolves them all, gold, ſilver, and platina excepted, though it has even leſs affinity with them than they have with that portion of phlogiſton which muſt be loſt before they can diſſolve in any acid. The reaſon of this is, that it unites with phlogiſton, unleſs when in too diluted a ſtate; and the heat produced by its union with phlogiſton is ſufficient to promote the ſolution of the metal. On the other hand, when very concentrated, it cannot diſſolve them: becauſe the acid does not then contain fire enough to throw the phlogiſton into an aerial form, and reduce the ſolid to a liquid.

339 Why it cannot diſſolve them when much concentrated.

340 In what caſes the marine acid can diſſolve metals, and when it cannot.

The marine acid dephlogiſticates metals leſs powerfully than any other. It can make no ſolution, or at leaſt can operate but very ſlowly, without heat, in thoſe caſes where the metallic calx has a ſtronger affinity with that portion of the phlogiſton which muſt be loſt, than the acid: nor can it operate briſkly even where the attraction is ſtronger, provided, the quantity of acid be ſmall; becauſe ſuch a little quantity of acid does not contain fire enough to volatilize the phlogiſton: and hence heat is neceſſary to aſſiſt the marine acid in diſſolving lead. When dephlogiſticated, it acts more powerfully.

341 Why copper and iron precipitate one another.

It has been obſerved, that copper and iron mutually precipitate one another. If a piece of copper be put into a ſaturated ſolution of iron freſh made, no precipitation will enſue for 12 hours, or even longer, if the liquor be kept cloſe from the air; but if the liquor be expoſed to the open air, the addition of volatile alkali will ſhow, in 24 hours, that ſome of the copper has been diſſolved, or ſooner, if heat be applied, and a calx of iron is precipitated. The reaſon of this will be underſtood from the following ſtate of the affinities.

Quieſcent.		Divellent.	
Vitriolic acid to calx of iron	270	Vitriolic acid to copper	260
Copper to its phlogiſton	360	Calx of iron to phlogiſton	250
	360		510

In this caſe no decompoſition can take place, becauſe the ſum of the divellent affinities is leſs than that of the quieſcent; but in the ſecond, when much of the phlogiſton of the iron has eſcaped, the affinity of the calx of iron to the acid is greatly diminiſhed, at the ſame time that the affinity of the calx to phlogiſton is augmented. The ſtate of the affinities may therefore be ſuppoſed as follows.

Quieſcent.		*Divellent.*	
Vitriolic acid to calx of iron	240	Vitriolic acid to copper	260
Copper to its phlogiſton	360	Calx of iron to phlogiſton	370
	600		630

342 Increaſe of the attraction of calx of iron to phlogiſton demonſtrated.

The increaſe of affinity of the calx of iron to phlogiſton is not a mere ſuppoſition; for if we put ſome freſh iron to a ſolution of the metal ſo far dephlogiſticated as to refuſe to cryſtallize, ſo much of the phlogiſton will be regained that the impoveriſhed ſolution will now yield cryſtals. The reaſon why the increaſed quantity of phlogiſton does not enable the acid to re-act upon the metal is, becauſe it is neither ſufficiently large, nor attracted with a ſufficient degree of force, to which the acceſs of air and heat employed contribute conſiderably. The diminution of attraction in calces of iron for acids is evident, not only from this but many other experiments; and particularly from the neceſſity of adding more acid to a turbid ſolution of iron in order to re-eſtabliſh its tranſparency.

343 Calces of copper precipitate dephlogiſticated ſolutions of iron.

A dephlogiſticated ſolution of iron is alſo precipitated by the calces of copper. The ſame thing happens to a ſolution of iron in nitrous acid; only as the acid predominates greatly in this ſolution, ſome of the copper is diſſolved before any of the iron is precipitated. Copper precipitates nothing from ſolution of iron in the marine acid, though expoſed to the open air for 24 hours.

344 Martial vitriol procured by precipitation of copper leſs fit for dyeing than the common.

Solution of copper in the vitriolic acid is inſtantly precipitated by iron; the reaſon of which is plain from the common table of affinities: and hence the foundation of the method of extracting copper, by means of iron, from ſome mineral waters. The precipitated ſolution affords a vitriol of iron, but of a paler kind than that commonly met with, and leſs fit for dyeing, as being more dephlogiſticated: the reaſon of which is, that copper contains more phlogiſton than iron: old iron is alſo uſed which has partly loſt its phlogiſton.

345 Solution of copper ſcarcely decompoſed by caſt iron.

giſton. Hence the iron is more dephlogiſticated by precipitating copper than by mere diſſolution in the vitriolic acid; and hence caſt iron, according to the obſervations of Mr Schlutter, will ſcarcely precipitate a ſolution of copper; becauſe it contains leſs phlogiſton than bar-iron, as Mr Bergman has informed us.

346 Why a ſaturated ſolution of ſilver can ſcarce be precipitated by iron.

Mr Kirwan always found ſilver eaſily precipitated by means of iron from its ſolution in nitrous acid; though Bergman had obſerved that a ſaturated ſolution of ſilver could not be thus precipitated without great difficulty, even though the ſolution were diluted and and an exceſs of acid added to it. What precipitation took place could only be accompliſhed by ſome kinds of iron. The reaſon of this Mr Kirwan ſuppoſes to be, that the ſolution, even after it is ſaturated, takes up ſome of the ſilver in its metallic form; which Mr Scheele has alſo obſerved to take place in quickſilver. The laſt portions of both theſe metals when diſſolved in ſtrong nitrous acid, afford no air, and conſequently are not dephlogiſticated. This compound of calx, therefore, and of ſilver in its metallic ſtate, it may reaſonably be ſuppoſed cannot be precipitated by iron, as the ſilver in its metallic form prevents the calx from coming into contact with the iron, and extracting the phlogiſton from it; and for the ſame reaſon iron has been obſerved not to precipitate a ſolution of mercury in the nitrous acid.

347 Of the precipitation of zinc and iron by one another.

Zinc cannot precipitate iron, as Mr Bergman has ſhown, until the ſolution of the latter loſes part of its phlogiſton. Hence we may underſtand why Newmann denied that iron can be precipitated by means of zinc. Mr Kirwan, however, has found, that zinc does not precipitate iron from the nitrous acid; but on the contrary, that iron precipitates zinc. In a ſhort time the acid rediſſolves the zinc and lets fall the iron, owing to the calx of iron being too much dephlogiſticated. Iron, however, will not precipitate zinc either from the vitriolic or marine acids. Moſt of the metallic ſubſtances precipitated by iron from the nitrous acid are in ſome meaſure rediſſolved ſhortly after; becauſe the nitrous acid ſoon dephlogiſticates the iron too much, then lets it fall, reacts on the other metals, and diſſolves them.

348 Why copper ſometimes cannot precipitate ſilver.

Dr Lewis obſerves, that ſilver is ſometimes not precipitated by copper from the nitrous acid; which happens either when the acid is ſuperſaturated with ſilver by taking up ſome in its metallic form, or when the ſilver is not much dephlogiſticated. In this caſe, the remedy is to heat the ſolution and add a little more acid, which dephlogiſticates it further; but the nitrous acid always retains a little ſilver.

349 Blue vitriol cannot be formed by boiling a ſolution of alum with copper filings.

It has commonly been related by chemical authors, that blue vitriol will be formed by adding filings of copper to a boiling ſolution of alum. Mr Kirwan, however, has ſhowed this to be an error; for after boiling a ſolution of alum for 20 hours with copper filings, not a particle of the metal was diſſolved; the liquor ſtanding even the teſt of the volatile alkali. The alum indeed was precipitated from the liquor, but ſtill retained its ſaline form; ſo that the precipitation was occaſioned only by the diſſipation of the ſuperfluous acid.

350 Why tin cannot be precipitated in its metallic form.

No metal is capable of precipitating tin in its metallic form; the reaſon of which, according to Mr Kirwan, is, becauſe the precipitation is not the effect of a double affinity, but of the ſingle greater affinity of its menſtruum to every other metallic earth.

351 Why metals precipitated by tin are afterwards rediſſolved.

Metals precipitated from the nitrous acid by tin are afterwards rediſſolved, becauſe the acid ſoon quits the tin by reaſon of its becoming too much dephlogiſticated.

352 Precipitations by lead.

Lead precipitates metallic ſolutions in the vitriolic and marine acids but ſlowly, becauſe the firſt portions of lead taken up form ſalts very difficult of ſolution, which cover its ſurface, and protect it from the further action of the acid; at the ſame time it contains ſo little phlogiſton, that a great quantity of it muſt be diſſolved before it will diſſolve other metals. A ſolution of lead very much ſaturated cannot be precipitated by iron but with difficulty, if at all. Mr Kirwan conjectures that this may ariſe from ſome of the lead alſo being taken up in its metallic form, as is the caſe with mercury and ſilver. Iron will not precipitate lead from marine acid; for though a precipitate appears the acid is ſtill adhering to the metal. On the contrary, iron is precipitated from its ſolution in this acid by lead, though very ſlowly.

353 Precipitations of mercury by copper.

Mercury is quickly precipitated from the vitriolic acid by copper, though the difference between the ſum of the quieſcent and divellent affinities is but very ſmall. The precipitation, however, takes place, becauſe the calx of mercury has a ſtrong attraction for phlogiſton; and a very ſmall portion of what is contained in copper is ſufficient to revive it.

354 It cannot be precipitated by ſilver from vitriolic acid.

Silver, however, is not able to precipitate mercury from the vitriolic acid, unleſs it contains copper; in which caſe a precipitation will enſue: but on diſtilling ſilver and turpeth mineral, the mercury will paſs over in its metallic form; which ſhows that the affinity of the calx of mercury to phlogiſton is increaſed by heat, though the difference betwixt the divellent and quieſcent powers is very ſmall.

355 Why mercury and ſilver precipitate one another from the nitrous acid.

Mercury appeared to be precipitated by ſilver from the nitrous acid, though very ſlowly; but when the ſolution was made without heat, it was not at all precipitated. On the other hand, mercury precipitates ſilver from this acid, not by virtue of the ſuperiority of the uſual divellent powers, but by reaſon of the attraction of mercury and ſilver for each other; for they form partly an amalgam and partly a vegetation, ſcarcely any thing of either remaining in the ſolution.

356 Corroſive ſublimate cannot be precipitated by ſilver; but luna cornea may be decompoſed by mercury, and ſublimate by ſilver, in the dry way.

Silver does not precipitate mercury from the ſolution of corroſive ſublimate; but, on the contrary, mercury precipitates ſilver from the marine acid: and if a ſolution of *luna cornea* in volatile alkali be triturated with mercury, calomel will be formed; yet on diſtilling calomel and ſilver together, the mercury will paſs in its metallic form, and luna cornea will be formed. The ſame thing happens on diſtilling ſilver and corroſive ſublimate, the affinity of calx of mercury to phlogiſton increaſing with heat.

357 Precipitations of biſmuth.

Biſmuth precipitates nothing from vitriol of copper in 16 hours; nor does copper from vitriol of biſmuth. The two metallic ſubſtances, however, alternately precipitate one another from the nitrous acid, which proceed from their different degrees of dephlogiſtication.

358 Nickel precipitated by zinc.

Nickel will ſcarcely precipitate any metal except it be reduced to powder. A black powder is precipitated by means of zinc from the ſolution of nickel

Solution and Precipitation.

in the vitriolic and nitrous acids, which has been ſhown by Bergman to conſiſt of arſenic, nickel, and a little of the zinc itſelf. The latter, however, precipitates nickel from the marine acid.

359 Iron and nickel will ſcarcely precipitate one another.

The ſolutions of iron and nickel in the vitriolic acid mutually act upon theſe metals; but neither of them will precipitate the other in 24 hours, though on remaining longer at reſt iron ſeems to have the advantage. Iron, however, evidently precipitates nickel from the nitrous acid; and though nickel ſeems to precipitate iron, yet this ariſes only from the gradual dephlogiſtication of the iron.

360 Precipitation of copper, lead, and biſmuth by nickel.

Copper is precipitated in its metalic form from the vitriolic, nitrous, and marine acids, by nickel. The vitriolic and nitrous ſolutions of lead ſeem to act upon it without any decompoſition, the calces uniting to each other. Lead ſeems for ſome time to be acted upon in the ſame manner by the vitriolic and nitrous ſolutions of nickel, but at laſt nickel ſeems to have the advantage; but a black precipitate appears which ever of them is put into the ſolution of the other. However, nickel readily precipitates vitriolic and nitrous ſolutions of biſmuth; but in the marine acid both theſe ſemimetals are ſoluble in the ſolutions of each other: yet nickel precipitates biſmuth very ſlowly, and only in part; while biſmuth precipitates a red powder, ſuppoſed by Mr Kirwan to be ochre, from the ſolution of nickel.

361 Zinc cannot precipitate cobalt.

Cobalt is not precipitated by zinc either from the vitriolic or nitrous acids, though it ſeems to have ſome effect upon it when diſſolved in that of ſea-ſalt.

362 Cobalt precipitated by iron.

Iron precipitates cobalt from all the three acids, yet much of the ſemimetal is retained in the vitriolic and nitrous ſolutions of it, particularly the latter; which, after letting fall the cobalt, takes it up again, and lets fall a dephlogiſticated calx of iron.

363 Nickel precipitates ſome heterogeneous matter from it.

Nickel alſo, though it does not precipitate cobalt itſelf, as appears by the remaining redneſs of the ſolution, yet conſtantly precipitates ſome heterogeneous matter from it. Solution of cobalt in the marine acid becomes colourleſs by the addition of nickel.

364 ſolutions of cobalt let fall a white powder on the addition of biſmuth or copper.

Biſmuth is ſoluble in the vitriolic and nitrous ſolutions of cobalt, and throws down a ſmall white precipitate, but does not affect the metallic part. Nor can we attribute theſe ſolutions in vitriolic acid to any exceſs in that acid, as they are dilute and made without heat. Copper alſo precipitates from the ſolution of cobalt a white powder ſuppoſed to be arſenic.

365 Precipitations of and by regulus of antimony.

The regulus of antimony has no effect on ſolution of copper in vitriolic acid, nor is precipitated by it from the ſame acid; but it diſſolves ſlowly in vitriol of antimony. With ſolution of vitriol of lead it becomes red in 16 hours, but is ſcarcely precipitated by lead from the vitriolic acid. Powdered regulus alſo precipitates vitriol of mercury very ſlightly. Biſmuth neither precipitates nor is precipitated by the regulus in 24 hours from the vitriolic acid. Tin precipitates the regulus from the nitrous acid; but if regulus be put into a ſolution of tin in the ſame acid, neither of the metals will be found in the liquid in 16 hours, either by reaſon of the dephlogiſtication or of the union of the calces to each other.

366 A triple ſalt formed by iron, regulus of antimony, and marine acid.

Iron does not precipitate regulus of antimony entirely from the marine acid; but ſeems to form a triple ſalt, conſiſting of the acid and both calces. The regulus may alſo be diſſolved by marine ſalt of iron.

367 Another formed by regulus of antimony, marine acid, and copper.

Copper does not precipitate regulus of antimony from marine acid in 16 hours; and if the regulus be put into marine ſalt of copper, it will be diſſolved, and volatile alkalies will not give a blue, but a yellowiſh white precipitate; ſo that here alſo a triple ſalt is formed.

368 Precipitations of and by arſenic.

Solution of arſenic in vitriolic acid acts upon iron, lead, copper, nickel, and zinc; but ſcarce give any precipitate: neither is arſenic precipitated by iron from the nitrous acid, though it is by copper, and even ſilver gives a ſlight white precipitate. Regulus of arſenic, however, precipitates ſilver completely in 16 hours: whence the former precipitate ſeems to be a triple ſalt. Mercury alſo ſlightly precipitates arſenic from the nitrous acid, and ſeems to unite with it, though it is itſelf precipitated by regulus of arſenic in 24 hours.

369 Regulus of arſenic precipitated by biſmuth from the nitrous acid;

Biſmuth ſlightly precipitates arſenic from ſpirit of nitre, but regulus of arſenic forms a copious precipitate in the nitrous ſolution of biſmuth; ſo that Mr Kirwan is of opinion that the calces unite. It is not precipitated from this acid by nickel, but the calces unite. Though regulus of arſenic produces a copious precipitate in the ſolution of nickel in nitrous acid, yet the liquor remains green; ſo that the nickel is certainly not precipitated. The white precipitate in this caſe ſeems to be arſenic ſlightly dephlogiſticated. Regulus of arſenic alſo produces a white precipitate in the nitrous ſolution of cobalt, but the liquor ſtill continues red.

370 And by copper from the marine acid.

Regulus of arſenic is precipitated from the marine acid by copper; but the precipitate does not ſtrike a blue colour with volatile alkali, becauſe the metal unites with the arſenic. The arſenic is alſo precipitated by iron. Tin is ſoluble in marine ſolution of arſenic, but Mr Kirwan could not obſerve any precipitation; nor does regulus of arſenic precipitate tin. Neither biſmuth nor regulus of arſenic precipitate each other from marine acid in 16 hours. Regulus of antimony is alſo acted upon by the marine ſolution of arſenic, though it cauſes no precipitate, nor does the regulus of arſenic precipitate it.

§ 2. *Of the Quantities of Acid, Alkali, &c. contained in different Salts, with the Specific Gravity of the Ingredients.*

It is a problem by which the attention of the beſt modern chemiſts has been engaged, to determine the quantity of acid exiſting in a dry ſtate in the various compound ſalts, reſulting from the union of acid with alkaline, earthy, and metallic ſubſtances. In this way Mr Kirwan has greatly excelled all others, and determined the matter with an accuracy and preciſion altogether unlooked for. His deciſions are founded on the following principles.

371 Specific gravity of bodies how found.

1. That the ſpecific gravity of bodies is their weight divided by an equal bulk of rain or diſtilled water; the latter being the ſtandard with which every other body is compared.

2. That if bodies ſpecifically heavier than water be weighed in air and in water, they loſe in water part of the weight which they were found to have in air;

and

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and that the weight ſo loſt is juſt the ſame as that of an equal bulk of water; and conſequently, that their ſpecific gravity is equal to their weight in air, or abſolute weight divided by their loſs of weight in water.

3. That if a ſolid, ſpecifically heavier than a liquid, be weighed firſt in air and then in that liquid, the weight it loſes is equal to the weight of an equal volume of that liquid; and conſequently, if ſuch ſolid be weighed firſt in air, then in water, and afterwards in any other liquid, the ſpecific gravity will be as the weight loſt in it by ſuch ſolid, divided by the loſs of weight of the ſame ſolid in water. This method of finding the ſpecific gravity of liquids, our author found more exact than that by the aerometer, or the compariſons of the weights of equal meaſures of ſuch liquids and water, both of which are ſubject to ſeveral inaccuracies.

372
To find the weight of an equal bulk of water where the ſpecific gravity is known.

4. That where the ſpecific gravity of bodies is already known, we may find the weight of an equal bulk of water; it being as the quotient of their abſolute weight divided by their ſpecific gravities: and this he calls their loſs of weight in water.

Thus where the ſpecific gravity and abſolute weight of the ingredients of any compound are known, the ſpecific gravity of ſuch compound may eaſily be calculated; as it ought to be intermediate betwixt that of the lighter and that of the heavier, according to their ſeveral proportions: and this Mr Kirwan calls the *mathematical* ſpecific gravity.

373
Mathematical ſpecific gravity explained.

But in fact the ſpecific gravity of compounds, found by actual experiment, ſeldom agrees with that found by calculation; but is often greater, without any diminution of the lighter ingredient.

374
Increaſed denſity of mixtures accounted for.

This increaſe of denſity, then, Mr Kirwan ſuppoſes to ariſe from a cloſer union of the component parts to each other than either had ſeparately with its own integrant parts; and this more intimate union muſt, he thinks, proceed from the attraction of theſe parts to each other: for which reaſon he ſuppoſed, that this attraction might be eſtimated by the increaſe of denſity or ſpecific gravity, and was proportionable to it; but ſoon found that he was miſtaken in this point.

375
Weights of different kinds of air

With regard to the abſolute weights of ſeveral ſorts of air, our author adheres to the computations of Mr Fontana, at whoſe experiments he was preſent; the thermometer being at 55°, and the barometer at 29½ inches, or nearly ſo. Theſe weights were as follow:

Cubic inch of	common air,	0.385
	fixed air,	0.570
	marine acid air,	0.654
	nitrous air,	0.399
	vitriolic acid air,	0.778
	alkaline air,	0.2
	inflammable air,	0.03

376
Method of finding the quantity of pure acid contained in ſpirit of ſalt.

Mr Kirwan begins his inveſtigations with the marine acid; endeavouring firſt to find the exact quantity of pure acid it contains at any given ſpecific gravity, and then by means of it determining the weight of acid contained in all other acids. For if a given quantity of pure fixed alkali were ſaturated, firſt by a certain quantity of ſpirit of ſalt, and then by determined quantities of the other acids, he concluded, that each of theſe quantities of acid liquor muſt contain the ſame quantity of acid; and this being known, the remainder, being the aqueous part, muſt alſo be known. This concluſion, however, reſted entirely on the ſuppoſition that the ſame quantity of all the acids was requiſite for the ſaturation of a given quantity of fixed alkali; for if ſuch given quantity of fixed alkali might be ſaturated by a ſmaller quantity of one acid than of another, the concluſion fell to the ground. The weight of the neutral ſalts produced might indeed determine this point in ſome meaſure; but ſtill a ſource of inaccuracy remained; to obviate which he uſed the following expedient. 1. He ſuppoſed the quantities of nitrous and vitriolic acids neceſſary to ſaturate a given quantity of fixed alkali exactly the ſame as that of marine acid, whoſe quantity he had determined; and to prove the truth of this ſuppoſition, he obſerved the ſpecific gravity of the ſpirit of nitre and oil of vitriol he employed, and in which he ſuppoſed, from the trial with alkalies, a certain proportion of acid and water. He then added to theſe more acid and water, and calculated what the ſpecific gravity ſhould be on the above ſuppoſition; and finding the reſult agreeable with the ſuppoſition, he concluded the latter to be exact. The following experiments were made on the marine acid.

Two bottles were filled nearly to the top with diſtilled water, of which they contained in all 1399.9 grains, and ſucceſſively introduced into two cylinders filled with marine air; and the proceſs was renewed, until the water had imbibed, in 18 days, about 794 cubic inches of the marine air. 377 Method of finding the ſpecific gravity of ſpirit of ſalt.

The thermometer did not riſe all this time above 55°; nor ſink, unleſs perhaps at night, above 50°; the barometer ſtanding between 29 and 30 inches. This dilute ſpirit of ſalt then weighed 1920 grains; that is, 520.1 more than before; the weight of the quantity of marine air abſorbed. The ſpecific gravity of the liquor was found to be 1.225. Its loſs of weight in water (that is, the weight of an equal bulk of water) ſhould then be 1567.346 nearly; but it contained only, as we have ſeen, 1399.9 grains of water: ſubtracting this therefore from 1567.346, the remainder (that is, 167.446) muſt be the loſs of 520.1 grains of marine acid; and conſequently the ſpecific gravity of the pure marine acid, in ſuch a condenſed ſtate as when it is united to water, muſt be $\frac{520.1}{167.446}$, or 3.100.

Still, however, it might be ſuſpected, that the denſity of this ſpirit did not entirely proceed from the mere denſity of the marine acid, but in part alſo from the attraction of this acid to water; and though the length of time requiſite to make the water imbibe this quantity of marine acid air, naturally led to the ſuppoſition that the attraction was not very conſiderable, yet the following experiment was more ſatisfactory. He expoſed 1440 grains of this ſpirit of ſalt to marine acid air for five days, the thermometer being at 50°, or below; and then found that it weighed 1562 grains, and conſequently had imbibed 122 grains more. Its ſpecific gravity was then 1.253, which was preciſely what it ſhould have been by calculation.

Being now ſatisfied that the proportion of acid in ſpirit of ſalt was diſcovered, our author determined to find it in other acids alſo. For this purpoſe he took 180 grains of very ſtrong oil of tartar *per deliquium*, and found that it was ſaturated by 180 grains of ſpirit of ſalt, whoſe ſpecific gravity was 1.225; and by 378 To find the proportion of pure air in other acid liquors.

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calculation it appeared, that 180 grains of this spirit contained 48.7 grains of acid, and 131.3 of water. Hence he drew up a table of the specific gravities of acid liquors containing 48.7 grains of pure acid, with different proportions of water, from 50 to 410 parts; the liquor with the first proportion having a specific gravity of 1.497, and the latter weighing only 1.074. Mr Baume had determined the specific gravity of the strongest spirit of salt made in the common manner to 1.187, and Bergman 1.190; but we are told in the Paris Memoirs for 1700, that Mr Homberg had produced a spirit whose specific gravity was 1.300; and that made by Dr Priestley, by saturating water with marine acid air, must have been about 1.500. The spirit of salt, therefore, whose specific gravity is 1.261, has but little attraction for water, and therefore attracts none from the air; for which reason also it does not heat the ball of a thermometer, as the vitriolic and nitrous acids do; though Mr Cavallo found that this also had some effect upon the thermometer. Common spirit of salt, Mr Kirwan informs us, is always adulterated with vitriolic acid, and therefore unfit for these trials.

379 Quantities of acid, water, and alkali in digestive salt.

Mr Kirwan now set about investigating the quantity of acid, water, and fixed alkali, in digestive salt, or a combination of the marine acid with vegetable alkali. For this purpose he took 100 grains of a solution of tolerably pure vegetable alkali, that had been three times calcined to whiteness, the specific gravity of which was 1.097; diluting also the spirit of salt with different portions of water; the specific gravity of one sort being 1.015, and of another 1.098. He then found that the above quantity of solution of the vegetable alkali required for its saturation 27 grains of that spirit of salt whose specific gravity was 1.098, and 23.35 grains of that whose specific gravity was 1.115. Now, 27 grains of spirit of salt, whose specific gravity is 1.098, contain 3.55 grains of marine acid, as appears by calculation. The principles on which calculations of this kind are founded, our author gives in the words of Mr Cotes.

380 How to find the specific gravities of the different ingredients.

"The data requisite are the specific gravities of the mixture and of the two ingredients. Then, as the difference of the specific gravities of the mixture and the lighter ingredient is to the difference of the specific gravities of the mixture and the heavier ingredient; so is the magnitude of the heavier to the magnitude of the lighter ingredient. Then, as the magnitude of the heavier, multiplied into its specific gravity, is to the magnitude of the lighter multiplied into its specific gravity; so is the weight of the heavier to the weight of the lighter. Then, as the sum of these weights is to the weight of either ingredient; so is the weight given to the weight of the ingredient sought." Thus, in the present case, 1.098—1.000=.098 is the magnitude of the heavier ingredient, viz. the marine acid, and .098×3.100=0.3038 the weight of the marine acid; and on the other hand, 3.100—1.098=2.002, the magnitude of the water; and 2.002×1.000=2.002 its weight; the sum of these weights is 2.3058: then if 2.3058 parts of spirit of salt contain 0.3038 parts acid, 27 grains of this spirit of salt will contain 3.55 acid. In the same manner it will be found, that 23.35 grains of spirit of salt, whose specific gravity is 1.115, contains 3.55 grains acid.

Our author describes very particularly his method of making the saturation of the alkali with the acid; which, as it is always difficult to hit with precision, we shall here transcribe. "It was performed by putting the glass cylinder which contained the alkaline solution on the scale of a very sensible balance, and at the same time weighing the acid liquor in another pair of scales; when the loss of weight indicated the escape of nearly equal quantities of fixed air contained in the solution. Then the acid was gradually added by dipping a glass rod in it, to the top of which a small drop of acid adhered. With this the solution was stirred, and very small drops taken up and laid upon bits of paper stained blue with radish juice. As soon as the paper was in the least reddened, the operation was completed; so that there was always a very small excess of acid, for which half a grain was constantly allowed; but no allowance was made for the fixed air, which always remains in the solution. But as on this account only a small quantity of the alkaline solution was used, this proportion of fixed air must have been inconsiderable. If one ounce of the solution had been employed, this inappretiable portion of fixed air, would be sufficient to cause a sensible error; for the quantity of fixed air lost by the difference betwixt the weight added to the 100 grains and the actual weight of the compound was judged of; and when this difference amounted to 2.2 grains, the whole of the fixed air was judged to be expelled: and it was found to be so; as 100 grains of the alkaline solution, being evaporated to dryness, in the heat of 300°, left a residuum which amounted to 10½ grains, which contained 2.2 grains of fixed air."

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381 Mr Kirwan's method of saturating the acid and alkali with accuracy.

382 Quantity of mild and caustic vegetable alkali saturated by a given weight of marine acid.

The result of this experiment was, that 8.3 grains of pure vegetable alkali, freed from fixed air and water, or 10.5 of mild fixed alkali, were saturated by 3.55 grains of pure marine acid; and consequently the resulting neutral salt should, if it contained no water, weigh 11.85 grains: but the salts resulting from this union (the solution being evaporated to perfect dryness in a heat of 160 degrees, kept up for four hours) weighed at a medium 12.66 grains. Of this 11.85 grains were acid and alkali; therefore the remainder, *viz.* 0.81 grains, were water. An hundred grains of perfectly dry digestive salt contain 28 grains acid, 6.55 of water, and 65.4 of fixed alkali.

383 Nitrous acid, when pure, cannot be made to exist in an aerial form.

In his experiments on the nitrous acid, Mr Kirwan made use only of the dephlogisticated kind, which appears pure and colourless as water. "This pure acid (says he) cannot be made to exist in the form of air, as Dr Priestley has shown; for when it is deprived of water and phlogiston, and furnished with a due proportion of elementary fire, it ceases to have the properties of an acid, and becomes dephlogisticated air. Its proportion therefore could not be determined in spirit of nitre as the marine acid had been in spirit of salt in the last experiment."—To determine the matter, the following experiments were made.

384 How to determine the quantity of pure acid contained in spirit of nitre.

1. To 1962.25 grains of dephlogisticated spirit of nitre, whose specific gravity was 1.419, he gradually added 179.5 grains of distilled water; and when it cooled, the specific gravity of the mixture was found to be 1.389.

2. To 1984.5 of this 178.75 grains of water were then added, and the specific gravity of the mixture found to be 1.362.

3. An hundred grains of a solution of fixed vegetable

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table alkali, whoſe ſpecific gravity was 1.097, the ſame that had been formerly uſed in the experiments with ſpirit of ſalt, was found to be ſaturated by 11 grains of the ſpirit of nitre, whoſe ſpecific gravity was 1.419, by 12 of that whoſe ſpecific gravity was 1.389, and by 13.08 of that whoſe ſpecific gravity was 1.362. Theſe quantities were the medium of five experiments; and it was found neceſſary to dilute the acid with a ſmall quantity of water. When this was neglected, part of the acid was phlogiſticated, and flew off with the fixed air. Ten minutes were alſo allowed after each affuſion for the matters to unite; a precaution which was likewiſe found to be abſolutely neceſſary.

385 Proportion of acid in ſpirit of nitre to that in ſpirit of ſalt.

Upon the ſuppoſition, therefore, that a given quantity of vegetable fixed alkali is ſaturated by the ſame weight of both acids, we ſee that 11 grains of ſpirit of nitre, whoſe ſpecific gravity is 1.419, contain the ſame quantity of acid with 27 grains of ſpirit of ſalt, whoſe ſpecific gravity is 1.098, or 3.55 grains. The remainder of 11 grains, or 7.45 grains, is therefore mere water; and of conſequence, if the denſity of the acid and water had not been increaſed by their union,

386 To find the ſpecific gravity of the pure nitrous acid.

the ſpecific gravity of the pure nitrous acid ſhould be 11.8729. But the ſpecific gravity of the nitrous, as well as of the vitriolic acid, is augmented by its union with water; and therefore the loſs of its weight in water is not exactly, as it would appear by calculation from the above premiſes, according to the rules al-

387 How to determine the accrued denſity on mixing ſpirit of nitre with water.

ready laid down. To determine therefore the real ſpecific gravity of the acid in its natural ſtate, the quantity of *accrued* denſity muſt be found, and ſubtracted from the ſpecific gravity of the ſpirit of nitre, whoſe true mathematical ſpecific gravity will then appear. This our author endeavoured to effect by mixing different portions of ſpirit of nitre and water, remarking the degree of diminution they ſuſtained by ſuch union; but was never able to attain a ſufficient degree of exactneſs in the experiment. He had recourſe therefore to the following method, as affording more ſatisfaction, though not altogether accurate. Twelve grains of the ſpirit of nitre, whoſe ſpecific gravity by obſervation was 1.389, contained, as our author ſuppoſed from the former experiment, 3.55 grains of real acid, and 8.45 of water: then if the ſpecific gravity of the pure nitrous acid were 11.872, that of this compound acid and water ſhould be 1.371; for the loſs of 3.55 ſhould be 0.299, and the loſs of the water 8.45, the ſum of the loſſes 8.749. Now, $\frac{12}{8.749}=1.371$: but the ſpecific gravity, as already mentioned, was 1.389: therefore the accrued denſity was at leaſt 0.18. the difference betwixt 1.389 and 1.371. This calculation indeed is not altogether exact: but our author concludes, that 0.18 is certainly a near approximation to the degree of denſity that accrues to 3.55 grains of acid by their union to 7.45 grains of water: therefore, ſubtracting this from 1.419, we have nearly the mathematical ſpecific gravity of that proportion of acid and water, namely, 1.401.

388 To determine the mathematical ſpecific gravity of this acid

Again, ſince 11 grains of this ſpirit of nitre contain 3.55 grains acid, and 7.45 of water, its loſs of weight ſhould be $\frac{11}{1.401}=7.855$; and ſubtracting the loſs of the aqueous part from this, the remainder 0.45 is the loſs of the 3.55 grains acid; and conſequently the true ſpecific gravity of the pure and mere nitrous acid is $\frac{3.55}{0.405}=8.7654$. This being ſettled, the mathematical ſpecific gravity and true increaſe of denſity of the above mixtures will be found. Thus the mathematical ſpecific gravity of 12 grains of that ſpirit of nitre, whoſe ſpecific gravity, by obſervation, was 1.389, muſt be 1.355; ſuppoſing it to contain 3.55 grains acid and 8.45 of water. For the loſs of 3.55 grains acid is $\frac{3.55}{8.763}=0.405$, and the loſs of water 8.45; the ſum of theſe loſſes is 8.855. Then $\frac{12}{8.855}=1.355$; and conſequently the accrued denſity is 1.389—1.355=.034. In the ſame manner it will be found that the mathematical ſpecific gravity of 13.08 grains of that ſpirit of nitre, whoſe ſpecific gravity by obſervation was 1.362, muſt be 1.315; and conſequently its accrued denſity .047.

The whole of this, however, ſtill reſts on the ſuppoſition that each of theſe portions of ſpirit of nitre contain 3.55 grains of acid. To verify this ſuppoſition, our author examined the mathematical ſpecific gravities of the firſt mixture he had made of ſpirit of nitre and water in large quantities; for if the mathematical ſpecific gravities of theſe agreed exactly with thoſe of the quantities he had ſuppoſed in ſmaller portions of each, he could not but conclude that the ſuppoſitions of ſuch proportions of acid and water, as he had determined in each, were juſt. 389 Experiment to determine the quantity of real acid in ſpirit of nitre.

This being determined by proper calculations, Mr Kirwan next proceeded to conſtruct another table of ſpecific gravities, continuing his mixtures, till the mathematical ſpecific gravities found by obſervation nearly coincided with thoſe made by calculation. In this table the ſpirit of nitre was mixed with water in various proportions, but after a different manner from that obſerved with the ſpirit of ſalt. Nine grains of the ſpirit containing 3.55 grains of pure acid were mixed with 5.45 of water; the accrued denſity of the mixture was found to be nothing, the mathematical ſpecific gravity 1.537, and the ſpecific gravity by obſervation was found the ſame. When 10 grains of ſpirit were mixed with 6.45 of water, the accrued denſity was 0.009, the mathematical ſpecific gravity 1.458, and the ſpecific gravity by obſervation 1.467. In this manner he proceeded until 38.90 grains of water were mixed with 42.45 of ſpirit. In this caſe the accrued denſity was found to be 0.002, the mathematical ſpecific gravity 1.080, and the ſpecific gravity by obſervation 1.082. 390 Table of ſpecific gravities for ſpirit of nitre, how conſtructed.

The intermediate ſpecific gravities, in a table of this kind, may be found by taking an arithmetical mean betwixt the ſpecific gravities, by obſervation, betwixt which the deſired ſpecific gravity lies, and noting how much it exceeds or falls ſhort of ſuch arithmetical mean; and then taking alſo an arithmetical mean betwixt the mathematical ſpecific gravities betwixt which that ſought for muſt lie, and a proportionate exceſs or defect.

The ſpecific gravity of the ſtrongeſt ſpirit of nitre yet made, is, according to Mr Baume, 1.500, and according to Mr Bergman 1.586.

Our author next proceeded to examine the propor-

tion

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tion of acid, water, and fixed alkali in nitre, in a manner ſimilar to what he had already done with digeſtive ſalt; and found that 100 grains of perfectly dry nitre contained 28.48 grains of acid, 5.2 of water, and 66.32 of fixed alkali.

391 Quantity of acid, water, and alkali in nitre determined.

Some experiments of the ſame kind had been made by M. Homberg; the reſults of which our author compared with thoſe of his own. The ſpecific gravity of the ſpirit of nitre which M. Homberg made uſe of was 1.349; and of this, he ſays, one ounce two drachms and 36 grains, or 621 troy grains, are required to ſaturate one French ounce (472.5 troy) of dry ſalt of tartar. According to Mr Kirwan's computation, however, 613 grains are ſufficient; for the ſpecific gravity lies between the ſpecific gravities by obſervation 1.362 and 1.337, and is nearly an arithmetical mean between them. The correſponding mathematical ſpecific gravity lies between the quantities marked in Mr Kirwan's table 1.315 and 1.286, being nearly 1.300. Now the proportion of acid and water in this is 2.629 of acid and 7.465 of water; for 8.765—1.300=7.465 of water, and 8.765×.300=2.629 of acid; and the ſum of both is 10.044. Now, ſince 10.5 grains of mild vegetable alkali require 3.53 grains of acid for their ſaturation, 472.5 will require 159.7; therefore if 10.044 grains of nitre contain 2.629 grains acid, the quantity of this ſpirit of nitre requiſite to give 159.7 will be 613.2 nearly, and thus the difference with M. Homberg is only about eight grains.

392 Homberg's experiments compared with thoſe of Mr Kirwan.

393 Different reſults of Homberg and Kirwan's experiments accounted for.

M. Homberg ſays he found his ſalt, when evaporated to dryneſs, to weigh 186 grains more than before, but by Mr Kirwan's experiment, it ſhould weigh but 92.8 grains more than at firſt; the cauſe of which difference will be mentioned in treating of vitriolated tartar, as it cannot be entirely attributed to the difference of evaporation.

He alſo aſſerts, that one ounce (472.5 Troy grains) of this ſpirit of nitre contains 141 grains of Troy of real acid. According to Mr Kirwan's computation, however, it contains only 123.08 grains of real acid. But this difference evidently proceeds from his neglecting the quantity of water that certainly enters into the compoſition of nitre; for he proceeds on this analogy, 621 : 186.6 :: 472.5 : 141.

394 Mr Kirwan's experiments confirmed by one of Fontana.

Our author obſerves, that the proportion of fixed alkali aſſigned by him to nitre is fully confirmed by an experiment of Mr Fontana's inſerted in Rozier's Journal for 1778. He decompoſed two ounces of nitre by diſtilling it with a ſtrong heat for 18 hours. After the diſtillation there remained in the retort a ſubſtance purely alkaline, amounting to 10 French drachms and 22 grains. Now two French ounces contain 945 grains Troy, and the alkaline matter 607 grains of the ſame kind: according to Mr Kirwan's computation the two ounces of nitre ought to contain 625 grains of alkali. Such a ſmall difference he ſuppoſes to proceed from the loſs in transferring from one veſſel to another, weighing, filtering, evaporating, &c. Mr Kirwan alſo ſhows in a very particular manner the agreement of his calculations with the experiments of M. Lavoiſier on mercury diſſolved in ſpirit of nitre; but our limits will not allow us to inſert an account of them.

When finding the quantity of pure acid contained in oil of vitriol, our author made uſe of ſuch as was not dephlogiſticated; but, though pale, yet a little inclining to red. It contained ſome whitiſh matter, as he perceived by its growing milky on the affuſion of pure diſtilled water; but he imagines it was as pure as the kind uſed in all experiments.

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395 Experiments on oil of vitriol.

To 2519.75 grains of this oil of vitriol, whoſe ſpecific gravity was 1.819, he gradually added 180 grains of diſtilled water, and ſix hours after found its ſpecific gravity to be 1.771.—To this mixture he again added 178.75 grains of water, and found its ſpecific gravity, when cooled to the temperature of the atmoſphere, to be 1.719, at which time it was milky. The ſame quantity of the oil of tartar abovementioned was then ſaturated with each of theſe kinds of oil of vitriol in the manner already deſcribed. The ſaturation was effected (taking a medium of five experiments) by 6.5 grains of that whoſe ſpecific gravity was 1.819, by 6.96 grains of that whoſe ſpecific gravity was 1.771, and by 7.41 of that whoſe ſpecific gravity was 1.719.

396 Dilution of oil of vitriol why neceſſary in theſe experiments.

It was found neceſſary to add a certain proportion of water to each of theſe ſorts of oil of vitriol; for when they were not diluted, part of the acid was phlogiſticated, and went off with the fixed air; but knowing the quantity of water that was added, it was eaſy to find by the rule of proportion the quantity of each ſort of vitriol that was taken up by the alkali. Hence it was ſuppoſed, that each of theſe quantities of oil of vitriol of different denſities contained 3.55 grains of acid; as they ſaturated the ſame quantity of vegetable fixed alkali with 11 grains of ſpirit of nitre, which contained that quantity of acid.

397 To find the ſpecific gravity of pure vitriolic acid.

It was next attempted to find the ſpecific gravity of the pure vitriolic acid in a manner ſimilar to that by which the gravity of the nitrous acid was found; as it cannot be had in the ſhape of air, unleſs when united with ſuch a quantity of phlogiſton as quite alters its properties. The loſs of 6.5 grains of oil of vitriol, whoſe ſpecific gravity is 1.819, is $\frac{6.5}{1.819} = 3.572$; but as theſe 6.5 grains contained, beſides 3.55 of acid, 2.95 of water, the loſs of this muſt be ſubtracted from the entire loſs; and then the remainder, or 0.622, is the loſs of the pure acid part in that ſtate or denſity to which it is reduced by its union with water. The ſpecific gravity, therefore, of the pure vitriolic acid, in this ſtate of denſity, is $\frac{3.55}{0.622} = 5.707$. But to find its natural ſpecific gravity, we muſt find how much its denſity is increaſed by its union with this quantity of water: and in order to obſerve this, he proceeded as before with the nitrous acid. 6.96 grains of oil of vitriol, whoſe ſpecific gravity was 1.771, contained 3.55 of acid and 3.41 of water; then its ſpecific gravity by calculation ſhould be 1.726; for the loſs of 3.55 grains of acid is $\frac{3.55}{5.707} = 0.622$; the loſs of 3.41 grains of water is 3.41; the ſum of the loſſes 4.032: then $\frac{6.96}{4.032} = 17.16$; therefore the accrued denſity is 1.771—1.726=0.45. Taking this therefore from 1.819, its mathematical ſpecific gravity will be 1.774. Then the loſs of 6.5 grains of oil of vitriol, whoſe ſpecific gravity by obſervation is 1.819, will be found to be $\frac{6.5}{1.774} = 4.663$; but of this, 2.95 grains are the loſs

of

of the water it contains, and the remainder 0.714 are the loſs of the mere acid part. Then $\frac{3.55}{0.714}$ is nearly the true ſpecific gravity of the pure vitriolic acid. The ſpecific gravity of the moſt concentrated oil of vitriol yet made, is, according to M. Baume and Bergman, 2.125.

Mr Kirwan now conſtructed a table of the ſpecific gravities of vitriolic acids, of different ſtrengths, in a manner ſimilar to thoſe conſtructed for ſpirit of ſalt and ſpirit of nitre; but for which, as well as the others,

398
Quantity of acid, alkali, and water, in vitriolated tartar determined.

we muſt refer to Phil. Tranſ. vol. 71. He then proceeded to find the proportion of acid, water, and fixed alkali, in vitriolated tartar as he had before done in ſal digeſtivus and nitre.—He found the ſalts reſulting from the ſaturation of the ſame oil of tartar, with portions of oil of vitriol, of different ſpecific gravities, to weigh at a medium 12,45 grains. Of this weight only 11.85 grains were alkali and acid. The remainder, therefore, was water, *viz* 0.6 of a grain. Conſequently 100 grains of perfectly dry tartar vitriolate contain 21.58 grains acid, 4.82 of water, and 66.67 of fixed vegetable alkali.—In drying this ſalt, a heat of 240 degrees was made uſe of, to expel the adhering acid more thoroughly. It was kept in this heat for a quarter of an hour.

399
Difference with Mr Homberg accounted for.

According to Mr Homberg, one French ounce, or 472.5 grains troy, of dry ſalt of tartar, required 297.5 grains troy, of oil of vitriol, whoſe ſpecific gravity was 1.674 to ſaturate it: but by Mr Kirwan's calculation, this quantity of fixed alkali would require 325 grains; a difference which, conſidering the different methods they made uſe of for determining the ſpecific gravities (Homberg's method by menſuration, giving it always leſs than Mr Kirwan's) the different deſiccation of their alkalies, &c. may be accounted inconſiderable.

The ſalt produced, according to Mr Homberg, weighed 182 grains troy above the original weight of the fixed alkali; but by Kirwan's experiment, it ſhould weigh but 87.7 grains more. "It is hard to ſay (adds Mr Kirwan) how Mr Homberg could find this great exceſs of weight, both in nitre and tartar vitriolate; unleſs he meant by the weight of the ſalt of tartar the weight of the mere alkaline part diſtinct from the fixed air it contained: and indeed one would be tempted to think he did make the diſtinction; for in that caſe the exceſs of weight would be nearly ſuch as he determined it."

From Mr Homberg's calculations, he inferred that one ounce (472.5 grains) of oil of vitriol contains 291.7 grains of acid. Mr Kirwan computes the acid only at 213.3 grains; but Homberg made no allowance for the water contained in tartar vitriolate; and imagined the whole increaſe of weight proceeded from the acid that is united in it to the fixed alkali. Now the aqueous part in 560 grains of tartar vitriolate amounts to 36 grains; the remaining difference may be attributed to the different degrees of deſiccation, &c.

400
Specific gravity of the acetous acid.

On the acetous acid Mr Kirwan did not make any experiment; but by calculating from thoſe of Homberg, he finds that the ſpecific gravity of the pure acetous acid, free from ſuperfluous water, ſhould be 2.30. "It is probable (ſays Mr Kirwan), that its affinity to water is not ſtrong enough to cauſe any irregular increaſe in its denſity; at leaſt what can be expreſſed by three decimals: and hence its proportion of acid and water may always be calculated from its ſpecific quantity and abſolute weight."

An hundred parts of foliated tartar, or, as it ſhould rather be called, acetous tartar, contain, when well dried, 32 of fixed alkali, 19 of acid, and 49 parts of water.—The ſpecific gravity of the ſtrongeſt concentrated vinegar yet made is 1.069.—It is more difficult to find the point of ſaturation with the vegetable than with the mineral acids, becauſe they contain a mucilage that prevents their immediate union with alkalies; and hence they are commonly uſed in too great quantity: they ſhould be uſed moderately hot, and ſufficient time allowed them to unite.

401
Specific gravity of ſtrong vinegar.

402
Vegetable fixed alkali takes up an equal quantity of all the mineral acids.

From all the experiments above related, Mr Kirwan concludes, 1. That the fixed vegetable alkali takes up an equal quantity of the three mineral acids, and probably of all pure acids; for we have ſeen that 8.2 grains of pure vegetable alkali, that is, free from fixed air, take up 3.55 grains of each of theſe acids; and conſequently 100 parts of cauſtic fixed alkali would require 42.4 parts of acid to ſaturate them. But Mr Bergman has found that 100 parts of cauſtic fixed vegetable alkali take up 47 parts of the aerial acid; which, conſidering that his alkali might contain ſome water, differs but little from that already given. It ſhould ſeem, therefore, that alkalies have a certain determined capacity of uniting to acids, that is, to a given weight of acids; and that this capacity is equally ſatiated by a given weight of any pure acid indiſcriminately. This weight is about 2.35 of the vegetable alkali.

403
Quantity of the alkali neceſſary to ſaturate the acids.

2. That the three mineral acids, and probably all pure acids, take up 2.253 times their own weight of pure vegetable alkali, that is, are ſaturated by that quantity.

404
Increaſe of denſity in compound ſubſtances.

3. That the denſity accruing to compound ſubſtances, from the union of their compound parts, and exceeding its mathematical ratio, increaſes from a *minimum*, when the quantity of one of them is very ſmall in proportion to that of the other; to a *maximum*, when their qualities differ leſs: but that the attraction, on the contrary, of that part which is in the ſmalleſt quantity to that which is in the greater, is at its maximum when the accrued denſity is at its minimum; but not reciprocally: and hence the point of ſaturation is probably the maximum of denſity and the minimum of ſenſible attraction of one of the parts. Hence no decompoſition operated by means of a ſubſtance that has a greater affinity with one part of a compound than with the other, and than theſe parts have with each other, can be complete, unleſs the minimum affinity of this third ſubſtance be greater than the maximum affinity of the parts already united. Hence alſo few decompoſitions are complete, unleſs a double affinity intervenes; and hence the laſt portions of the ſeparated ſubſtance adhere ſo obſtinately to that with which it was firſt united, as all chemiſts have obſerved.—Thus, though acids have a greater affinity to phlogiſton than the earths of the different metals have to it, yet they can never totally dephlogiſticate theſe earths but only to a certain degree; ſo, though atmoſpheric air, and particularly dephlogiſticated air, attracts phlogiſton more ſtrongly than the nitrous acid does, yet not even dephlogiſticated air can deprive the nitrous acid totally of its phlogiſton; as is evident from the

405
Why decompoſitions are ſometimes incomplete, and otherwiſe.

406
Why the laſt portions of a ſubſtance obſtinately adhere to that with which it was united.

407
Acids can never totally dephlogiſticate metallic earths.

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the red colour of the nitrous acid, when nitrous air and dephlogiſticated air are mixed together. Hence mercury precipitated from its ſolution in any acid, even by fixed alkalies, conſtantly retains a portion of the acid to which it was originally united, as Mr Bayen has ſhown. Thus alſo the earth of alum, when precipitated in like manner from its ſolution, retains part of the acid; and thus ſeveral anomalous decompoſitions may be explained.

408 Why precipitates of mercury and alum retain part of the acid.

409 Alkalies phlogiſticate concentrated acids.

4. That concentrated acids are in ſome meaſure phlogiſticated, and evaporate by union with fixed alkalies.

410 How to determine the quantity of pure acid in any ſubſtance.

5. That, knowing the quantity of fixed alkali in oil of tartar, we may determine the quantity of real pure acid in any other acid ſubſtance that is difficultly decompoſed; as the ſedative acid, and thoſe in vegetables and animals. For 10.5 grains of the mild alkali will always be ſaturated by 3.55 grains of real acid; and reciprocally, the quantity of acid in any acid liquor being known, the quantity of real alkali in any vegetable alkaline liquor may be found.

411 Specific gravity of fixed air determined.

Having thus determined the quantity of acid contained in the liquids of that kind uſually employed in chemiſtry, as well as the ſpecific gravities of the acids themſelves, Mr Kirwan became deſirous of inveſtigating the gravity of fixed and volatile alkalies. But as theſe ſubſtances are not eaſily preſerved from uniting themſelves with fixed air, he was led to conſider the gravity of this in its fixed ſtate, as an element neceſſary for the calculation of the quantities of the alkalies.

412 Specific gravity of fixed vegetable alkali inveſtigated.

To find the ſpecific gravity of the fixed vegetable alkali, our author proceeded in a manner ſimilar to that already deſcribed, excepting that he weighed it in ether inſtead of ſpirit of wine. The reſults of his experiments are.

413 Quantity of earth contained in it.

1. That 100 grains of this alkali contain about 6.7 grains of earth; which, according to Mr Bergman, is ſiliceous. It paſſes the filter along with it when the alkali is not ſaturated with fixed air; ſo that it ſeems to be held in ſolution in the ſame manner as in the *liquor ſilicum*.

414 Quantity of fixed air in oil of tartar and dry vegetable fixed alkali.

2. The quantity of fixed air in oil of tartar and dry vegetable fixed alkali is various at various times, and in various parcels of the ſame ſalt; but in the purer alkalies it may be reckoned at a medium 21 grains in 100; and hence the quantity of this alkali may very nearly be gueſſed at in any ſolution, by adding a known weight of any dilute acid to a given weight of ſuch a ſolution, and then weighing it again; for as 21 is to 100, ſo is the weight loſt to the weight of mild alkali in ſuch ſolution. The ſpecific gravity of mild and perfectly dry vegetable fixed alkali, four times calcined, free from ſiliceous earth, and containing 21 *per cent.* of fixed air, was found to be 5.0527. When it contains more fixed air the gravity is probably higher, except when it is not perfectly dry; and hence the ſpecific gravity of this alkali, when cauſtic, was ſuppoſed by Mr Kirwan to be 4.234. For this reaſon the fixed alkalies, when united to aerial acid, are ſpecifically heavier than when united either to the vitriolic or nitrous. Thus Mr R. Watſon, in the Philoſophical Tranſactions for 1770, informs us, that he found the ſpecific gravity of dry ſalt of tartar, including the ſiliceous earth it naturally contains, to be 2.761; whereas the ſpecific gravity of vitriolated tartar was only 2.636, and that of nitre 1.933. The reaſon why nitre is ſo much lighter than tartar vitriolate is, that it contains much more water, and the union of the acid with the water is leſs intimate.

415 Mr Watſon's account of the ſpecific gravity of ſalt of tartar, &c.

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416 Why nitre is ſo much lighter than vitriolated tartar.

417 Quantity of fixed air in pure vegetable alkalies determined by Mr Cavendiſh.

Impure vegetable fixed alkalies, ſuch as pearl-aſh, potaſhes, &c. contain more fixed air than the purer kind. According to Mr Cavendiſh, pearl-aſh contains 28.4 or 20.7 *per cent.* of fixed air. Hence in lyes made from theſe ſalts, of equal ſpecific gravities with thoſe of a purer alkali, the quantity of ſaline matter will probably be in the ratio of 28.4 or 28.7 to 21; but this additional weight is only fixed air. Much alſo depends on their age; the oldeſt containing moſt fixed air. Our author alſo gives a table of the ſpecific gravities of different ſolutions of vegetable fixed alkali, in a manner ſimilar to what he had done before with the acids. He begins with 64.92 grains of a ſolution containing 26.25 grains of ſalt, and 38.67 of water. The accrued denſity he finds to be .050, the mathematical ſpecific gravity 1.445, and the ſpecific gravity by obſervation 1.495. By continually diluting the ſolution containing the ſame quantity of ſalt, he brings the abſolute weight of it at laſt to 341.94 grains, of which 317.49 are water; the accrued denſity 0.01, the mathematical ſpecific gravity 1.061, and the ſpecific gravity by obſervation 1.062.

418 Quantity of acid taken up by mild fixed alkali exactly determined.

In a ſubſequent paper on this ſubject, Philoſophical Tranſactions, vol. 72, p. 179, our author corrects a ſmall miſtake concerning the quantity of acid taken up by 10.5 grains of mild vegetable alkali. In his former computations he had made no allowance for the ſmall quantity of earth contained in this quantity of alkali; which, though inconſiderable in it, becomes of conſequence where the quantities are large. The error, however, occaſioned by this omiſſion, is ſenſible in his calculations concerning the quantities of acid alkali, &c. contained in the neutral ſalts, as well as in that concerning the vegetable alkali. When the correction is properly made, he ſays, it will be found that 100 grains of ſuch alkali, free from earth, water, and fixed air, take up 46.77 of the mineral acids, that is, of the mere acid part; and 100 grains of common mild vegetable alkali take up 36.23 grains of real acid. An hundred grains of perfectly dry tartar vitriolate contain 30.21 of real acid, 64.61 of fixed alkali, and 5.18 of water. Cryſtallized tartar vitriolate loſes only one *per cent.* of water in a heat in which its acid is not ſeparated in any degree; and therefore contains 6.18 of water. An hundred grains of nitre, perfectly dry, contain 30.86 of acid, 66 of alkali, and 3.14 of water; but in cryſtallized nitre the proportion of water is ſomewhat greater; for 100 grains of thoſe cryſtals being expoſed to a heat of 180° for two hours, loſt three grains of their weight without exhaling any acid ſmell; but when expoſed to a heat of 200 degrees, the ſmell of the nitrous acid is diſtinctly perceived. Hence 100 grains of cryſtallized nitre contain 29.89 of mere acid, 63.97 of alkali, and 6.14 of water. An hundred grains of digeſtive ſalt perfectly dry, contain 29.68 of marine acid, 63.47 of alkali, and 6.85 of water. One hundred grains of cryſtallized digeſtive ſalt loſe but one grain of their weight before the ſmell of the marine acid is perceived; and hence they contain 7.85 grains of water.

419 Of the quantity of ingredients in vitriolated tartar;

420 In nitre;

421 In digeſtive ſalt.

Another miſtake, more difficult to be corrected, was his ſuppoſing the mixtures of oil of vitriol and water, and ſpirit of nitre and water, had attained their maximum of denſity when they had cooled to the tempera-

ture

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ture of the atmoſphere; which at the time he made the experiment was between 50° and 60° of Fahrenheit. The mixture with oil of vitriol had been ſuffered to ſtand ſix hours; but when the acid was ſo much diluted as to occaſion little or no heat, it was allowed to ſtand only for a very little time. Several months afterwards, however, many of theſe mixtures were found much denſer than when he firſt examined them; and it was diſcovered, that at leaſt twelve hours reſt was neceſſary before concentrated oil of vitriol, to which even twice its weight of water is added, can attain its utmoſt denſity; and ſtill more when a ſmaller proportion of water is uſed. Thus when he made the mixture of 2519.75 grains of oil of vitriol, whoſe ſpecific gravity was 1.819, with 180 of water, he found its denſity ſix hours after 1.771, but after 24 hours it was 1.798: and hence, according to the methods of calculating already laid down, the accrued denſity was at leaſt .064 inſtead of .045. But by uſing oil of vitriol ſtill more concentrated, whoſe ſpecific gravity was 1.8846, he was enabled to make a ſtill nearer approximation; and found, that the accrued denſity of oil of vitriol, whoſe ſpecific gravity is 1.819, amounts to 0.104, and conſequently its mathematical ſpecific gravity is 1.715. Six grains and a half of this oil of vitriol contained, as has been already obſerved, 3.55 of mere acid, and the remainder was water. The weight of an equal bulk of water is 3.79 grains; and ſubtracting from this the weight of the water that enters into the compoſition of the oil of vitriol, it will be found, that the weight of a bulk of water equal to the acid part is 0.84; and conſequently the ſpecific gravity of the mere acid part is 4.226. Thus, by conſtantly allowing the mixtures to reſt at leaſt 12 hours, until the oil of vitriol was diluted with four times its weight of water, and then only ſix hours before the denſity of the mixtures was examined, he conſtructed another table, in which 1000 grains of liquor contained 612.05 of pure acid, 387.95 of water, the accrued denſity being .07, and the mathematical ſpecific gravity 1.877. Increaſing the quantity of water till the acid weighed 7000 grains, and the water 6387.95, he found the accrued denſity .059, and the mathematical ſpecific gravity 1.069. By a ſimilar correction of his experiments on the acid of nitre, he found its denſity to be 5.530; a ſimilar table was conſtructed for it, for which we refer our readers to the 72d volume of the Philoſophical Tranſactions.

422 Time required by mixtures of mineral acids and water to acquire their utmoſt denſity.

423 Alteration of the denſity of acids by various degrees of heat.

Theſe experiments were made when the thermometer ſtood between 50° and 60° of Fahrenheit; but, as it might be ſuſpected that the denſity of acids is conſiderably altered at different degrees of temperature, he endeavoured to find the quantity of this alteration in the following manner: To calculate what this denſity would be at 55°, he took ſome dephlogiſticated ſpirit of nitre, and examined its ſpecific gravity at different degrees of heat; which was found to be as follows,

Degrees of heat.	Specific gravity.
30	1.4653
46	1.4587
86	1.4302
120	1.4123

The total expanſion of this ſpirit of nitre, therefore, from 30 to 120 degrees, that is, by 90° of heat, was 0.0527; for 1.4650=4123+.0527. By which we ſee, that the dilatations are nearly proportional to the degrees of heat: for beginning with the firſt dilatation from 30 to 46 degrees, that is, by 16 degrees of heat, we find that the difference between the calculated and obſerved dilatations is only [illegible]; a difference of no conſequence in the preſent caſe, and which might ariſe from the immerſion of the cold glaſs-ball filled with mercury in the liquor. In the next caſe the difference is ſtill leſs, amounting only to [illegible].

With another, and ſomewhat ſtronger ſpirit of nitre, the ſpecific gravities were as follow:

Degrees of heat.	Specific gravity.
34	1.4750
49	1.4653
150	1.3792

Here alſo the expanſions were nearly proportional to the degrees of heat; for 116° of heat, the difference between 34 and 150, produce an expanſion of 0.0958; and 15° of heat, the difference between 34 and 49, produce an expanſion of 0.0097; and by calculation 0.0123: which laſt differs from the truth only by [illegible].

484 Strong ſpirit of nitre more expanded by heat than weak, and why.

From this experiment we ſee, that the ſtronger the ſpirit of nitre is, the more it is expanded by the ſame degree of heat; for if the ſpirit of nitre of the laſt experiment were explained in the ſame proportion as in the former, its dilatation, by 116 degrees of heat, ſhould be 0.0679; whereas it was found to be 0.0958.

As the dilatation of the ſpirit of nitre is far greater than that of water by the ſame degree of heat, and as it conſiſts only of acid and water; it clearly follows, that its ſuperior dilatability muſt be owing to the acid part: and hence the more acid that is contained in any quantity of ſpirit of nitre, the greater is its dilatability. We might therefore ſuppoſe, that the dilatation of nitre was intermediate betwixt the quantity of water it contains and that of the acid. But there exiſts another power alſo which prevents this ſimple reſult, *viz.* the attraction of the acid and water to each other, which makes them occupy leſs ſpace than the ſum of their joint volumes; and by this condenſation our author explains his phraſe of *accrued denſity*. Taking this into the account, we may conſider the dilatation of the ſpirit of nitre as equal to thoſe of the quantities of water and acid it contains, minus the condenſation they acquire from their mutual attraction; and this rule holds as to all other heterogeneous compounds.

425 Exact quantity of dilatation of ſpirit of nitre.

426 Of the quantities of acid and water contained in ſpirit of nitre.

To find the quantities of acid and water in ſpirit of nitre, whoſe ſpecific gravity was found in degrees of temperature different from thoſe for which the table was conſtructed, viz. 54°, 55°, or 56° of Fahrenheit, the ſureſt method is to find how much that ſpirit of nitre is expanded or condenſed by a greater or leſſer degree of heat; and then, by the rule of proportion, find what its denſity would be at 55°. But if this cannot be done, we ſhall approach pretty near the truth if we allow [illegible] for every 15° degrees of heat above or below 55° of Fahrenheit, when the ſpecific gravity is between 1.409 and 1.500, and [illegible] when the ſpecific gravity is between 1.600 and 1.800.—The dilatations of oil and ſpirit of vitriol were found to be exceedingly irregular, probably by reaſon of a white foreign matter, which is more or leſs ſuſpended or diſſolved in it, according to its greater or leſſer dilution; and

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and this matter our author did not ſeparate, as he intended to try the acid in the ſtate in which it is commonly uſed. In general he found that 15° of heat cauſed a difference of above [illegible] in its ſpecific gravity, when it exceeds 1.800, and of [illegible] when its ſpecific gravity is between 1.400 and 1.300—The dilatations of ſpirit of ſalt are very nearly proportional to the degrees of heat, as appears by the following table.

427 *Dilatation of ſpirit of ſalt by various degrees of heat.*

Degrees of heat.	Specific gravity.
33	1.1916
54	1.1860
66	1.1820
128	1.1631

Hence [illegible] ſhould be added or ſubtracted for every 21° above or below 55°, in order to reduce it to 55°, the degree for which its proportion of acid and water was calculated. The dilatability of this acid is much greater than that of water, and even than that of the nitrous acid of the ſame denſity.

428 *Quantity of pure acid taken up by various ſubſtances.*

Our author next proceeds to conſider the quantity of pure acids taken up at the point of ſaturation by the various ſubſtances they unite with.—He begins with the mineral alkali. Having rendered a quantity of this cauſtic in the uſual manner, and evaporating one ounce of the cauſtic ſolution to perfect dryneſs, he found it to contain 20.25 grains of ſolid matter. He was aſſured, that the watery part alone exhaled during evaporation, as the quantity of fixed air contained in it was very ſmall, and to diſſipate this a much greater heat would have been requiſite than that which he uſed. This dry alkali was diſſolved in twice its weight of water; and ſaturating it with dilute vitriolic acid, he found it to contain 2.25 grains of fixed air; that being the weight which the ſaturated ſolution wanted of being equal to the joint weights of water, alkali, and ſpirit of vitriol employed.

429 *Mineral alkali how prepared for theſe experiments.*

430 *Quantity of vitriolic acid neceſſary to ſaturate it.*

The quantity of mere vitriolic acid neceſſary to ſaturate 100 grains of pure mineral alkali was found to be 60 or 61 grains; the ſaturated ſolution thus formed being evaporated to perfect dryneſs weighed 36.5 grains; but of this weight only 28.38 were alkali and acid; the remainder, that is, 8.12 grains, therefore, were water. Hence 100 grains of Glauber's ſalt, perfectly dried, contained 29.12 of mere vitriolic acid, 48.6 of mere alkali, and 22.28 of water. But Glauber's ſalt cryſtallized contains a much larger proportion of water; for 100 grains of theſe cryſtals heated red hot loſt 55 grains of their weight; and this loſs Mr Kirwan ſuppoſes to ariſe merely from the evaporation of the watery part, and the remaining 45 contained alkali, water, and acid, in the ſame proportion as the 100 grains of Glauber's ſalt perfectly dried abovementioned. Then theſe 45 contained 13.19 grains of vitriolic acid, 21.87 of fixed alkali, and 9.94 of water: conſequently 100 grains of cryſtallized Glauber's ſalt contains 13.19 of vitriolic acid, 21.87 of alkali, and 64.94 of water.

431 *Quantity of ingredients in Glauber's ſalt.*

432 *Quantity of mineral alkali taken up by dephlogiſticated nitrous acid;*

On ſaturating the mineral alkali with dephlogiſticated nitrous acid, it was found that 100 grains of the alkali took up 57 of the pure acid in the experiment he moſt depended upon; though in ſome others this quantity varied by a few grains: he concludes, therefore, that the quantity of alkali taken up by this acid is nearly the ſame as that taken up by the vitriolic. Suppoſing this quantity to be 57 grains, then 100 grains of cubic nitre, perfectly dry, contain 30 of acid, 52.18 of alkali, and 17.82 of water: but cubic nitre cryſtallized contains ſomething more water; for 100 grains of theſe cryſtals loſe about four by gentle drying; therefore 100 grains of the cryſtallized ſalt contain 28.8 of acid, 50.09 of alkali, and 21.11 of water.

433 *By marine acid.*

An hundred grains of mineral alkali require from 63 to 66 or 67 grains of pure marine acid to ſaturate it; but Mr Kirwan ſuppoſes that one reaſon of this variety is, that it is exceeding hard to hit the true point of ſaturation. Allowing 66 grains to be the quantity required, then 100 grains of perfectly dry common ſalt contain nearly 35 grains of real acid, 53 of alkali, and 13 of water; but 100 grains of the cryſtallized ſalt loſe five by evaporation; ſo that 100 grains of theſe cryſtals contain 33.3 of acid, 50 of alkali, and 16.7 of water.

434 *Proportion of fixed air, alkali, and water, inveſtigated by this ſaturation.*

The proportion of fixed air, alkali, and water, was thus inveſtigated: 200 grains of theſe cryſtals were diſſolved in 240 of water; the ſolution was ſaturated by ſuch a quantity of ſpirit of nitre as contained 40 of pure nitrous acid; whence it was inferred that theſe 200 grains of ſalt of ſoda contained 70 of pure alkaline ſalt. The ſaturated ſolution weighed 40 grains leſs than the ſum of its original weight, and that of the ſpirit of nitre added to it; conſequently it loſt 40 grains of fixed air. The remainder of the original weight of the cryſtals therefore muſt have been water, *viz.* 90 grains. Conſequently 100 grains of theſe cryſtals contained 35 of alkali, 20 of fixed air, and 45 of water. This proportion differs conſiderably from that aſſigned by Mr Bergman and Lavoiſier, which our author imputes to their having made uſe of ſoda recently cryſtallized; but Mr Kirwan's had been made for ſome months, and probably loſt much water and fixed air by evaporation, which altered the proportion of the whole. According to the calculations of Bergman and Lavoiſier, 100 grains of this alkali take up 80 of fixed air. The ſpecific gravity of the cryſtallized mineral alkali, weighed in ether, found to be 1.421.

435 *Differences with M. Bergman and Lavoiſier accounted for.*

436 *Proportions of ingredients in volatile alkalies.*

The proportion of the different ingredients in volatile alkalies can only be had from the experiments lately made by Dr Prieſtley concerning alkaline air. He informs us, that [illegible] of a meaſure of this, and one meaſure of fixed air, ſaturate one another. Then, ſuppoſing the meaſure to contain 100 cubic inches, 185 cubic inches of alkaline air take up 100 of fixed air; but 185 cubic inches of alkaline air weigh at a medium 42.55 grains, and 100 cubic inches of fixed air weigh 57 grains; therefore 100 grains of pure volatile alkali, free from water, take up 134 of fixed air.

On expelling its aerial acid from a quantity of this volatile alkali in a concrete ſtate, and formed by ſublimation, he found, that 53 grains of it were fixed air: according to the preceding calculation, 100 grains of it ſhould contain 39.47 of real alkali, and 7.53 of water, the reſt being fixed air.—On ſaturating a quantity with the vitriolic, nitrous, and marine acids, 100 grains of the mere alkali were found to take up 106 of mere vitriolic acid, 115 of the nitrous, and 130 of the marine acid. The ſpecific gravity of the volatile alkali

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alkali weighed in ether (B) was 1.4076. The proportion of water in the different ammoniacal ſalts could not be found on account of their volatility; but was ſuppoſed to be very ſmall, as both volatile alkali and fixed air cryſtallize without the help of water when in an aerial ſtate.

437 Experiments on calcareous earth.

In making experiments on calcareous earth, it was firſt diſſolved in nitrous acid; and after allowing for the loſs of fixed air and water, 100 grains of the pure earth was found to take up 104 of nitrous acid; but only 91 or 92 of mere vitriolic acid were required to precipitate it from the nitrous ſolution.

438 Quantity of marine acid ſaturated by this earth.

Of the marine acid 100 grains of the pure calcareous earth require 112 for their ſolution. The liquor at firſt is colourleſs, but acquires a greeniſh colour by ſtanding.

439 Proportion of ingredients in natural gypſum;

Natural gypſum varies in its proportion of acid, water, and earth; 100 grains of it containing from 32 to 34 of acid and likewiſe of earth, and from 26 to 32 of water. The artificial gypſum contains 32 of earth, 29.44 of acid, and 38.56 of water. When well dried, it loſes about 24 of water; and therefore contains 42 of earth, 39 of acid, and 19 of water, *per* hundred.

440 In nitrous ſelenite;

Nitrous ſelenite (ſolution of calcareous earth in nitrous acid) carefully dried, contains 33.28 of acid, 32 of earth, and 34.72 of water.

441 In marine ſelenite.

The ſame quantity of marine ſelenite (ſolution of calcareous earth in marine acid), well dried, in ſuch a manner as to loſe no part of the acid, contain of the latter 42 56, of earth 38, and of water 19.44.

442 Calcined magneſia will not diſſolve in acids without heat.

Magneſia, when perfectly dry and free from fixed air, cannot be diſſolved in any of the acids without heat. Even the ſtrongeſt nitrous acid did not act upon it in 24 hours in the temperature of the atmoſphere; but in a heat of 180°, the mineral acids, diluted with four, or even ſix, times their quantity of water, had a very ſenſible effect upon it; but the quantity of acid diſſipated by heat rendered it impoſſible to aſcertain how much was neceſſary for ſolution, except by precipitation after it had been diſſolved. For this purpoſe the cauſtic vegetable alkali was employed; by which it appeared that 100 grains of pure magneſia take up 125 of mere vitriolic acid, 132 of the nitrous, and 140 of the marine. All of theſe ſolutions appeared to contain ſomething gelatinous; but none of them reddened vegetable blues; and that in the marine acid became greeniſh on ſtanding for ſome time.

443 Proportion of the ingredients in common Epſom ſalt;

An hundred grains of perfectly dry Epſom ſalt contain 45.67 of mere vitriolic acid, 36.54 of pure earth, and 17.83 of water. Solution of common Epſom ſalt, however, reddens vegetable blues, and therefore contains an exceſs of acid.

444 In nitrous Epſom.

A like quantity of nitrous Epſom, well dried, contains 35.64 of acid, 27 of pure earth, and 37.36 of water.

445 Cannot be found in marine Epſom.

The ſolution of marine Epſom cannot be tolerably dried without loſing much of its acid together with the water. The ſpecific gravity of this earth is 2.3296.

446 Earth of alum contains a great quantity of fixed air.

Moſt writers on chemiſtry have ſaid that earth of alum contains ſcarce any fixed air; but Mr Kirwan found that it contained no leſs than 26 *per cent.* though it had been previouſly kept red-hot for half an hour. It diſſolved with a moderate effervescence in acids until the heat was raiſed to 220°; after which the ſolution was found to have loſt weight in the proportion abovementioned.

447 Quantity of ingredients in alum.

An hundred grains of this earth, deprived of the fixed air, require 133 of the pure vitriolic acid to diſſolve them. The ſolution was made in a very dilute ſpirit of vitriol, whoſe ſpecific gravity was 1.093, and in which the proportion of acid to the water was nearly as 1 to 14. It contained a ſlight exceſs of acid, turning the vegetable blues to a browniſh red; but it cryſtallized when cold, and the cryſtals were of the form of alum. Our author, therefore, is of opinion, that this is the true proportion of acid and earth to be uſed in the formation of that ſalt, though there was not water enough to form large cryſtals.

448 This ſalt always contains an exceſs of acid.

Perceiving that the liquor contained an exceſs of acid, more earth was added; but thus it was found impoſſible to prevent it from tinging vegetable blues of a red colour until a precipitation was formed: and even when this was the caſe, though one part of the ſalt fell in the form juſt mentioned, yet the reſt would ſtill redden vegetable blues as before; though here our author doubts whether this be a mark of acidity. An hundred grains of alum, when dried, contain 42.74 of acid, 32.14 of earth, and 25.02 of water; but cryſtallized alum loſes 44 *per cent.* by deſiccation: therefore 100 grains of it contain 23.94 of acid, and 58.06 of water.

449 Proportion of pure earth of alum taken up by nitrous acid;

An hundred grains of this pure earth take up, as near as can be judged, 153 of pure nitrous acid. The ſolution ſtill reddened vegetable blues; but after the above quantity of earth was added, an inſoluble ſalt began to precipitate. The ſolution, when cold, became turbid, and could not be rendered quite clear by 500 times its quantity of water.

450 By marine acid.

An hundred and ſeventy-three grains of pure marine acid are required for the diſſolution of 100 grains of earth of alum, but the liquor ſtill reddened vegetable blues. After this an inſoluble ſalt was formed; but it is difficult to aſcertain the beginning of its formation preciſely both in this and the preceding caſes. The ſpecific gravity of pure argillaceous earth, containing 25 *per cent.* of fixed air, is 1.9901.

451 Experiments on metals.

In the experiments made by our author on metals, the acids employed were ſo far dephlogiſticated as to be colourleſs; the metals were for the moſt part reduced to filings, or to fine powder in a mortar.

452 Beſt method of diſſolving them.

They were added by little and little to their reſpective menſtrua; much more being thus diſſolved than if the whole had been thrown in at once, and the ſolution was performed in glaſs vials with bent tubes.

453 Proportion of iron taken up by the vitriolic acid.

An hundred grains of bar-iron, in the temperature of 56°, require for their ſolution 190 grains of the real acid, whoſe proportion to that of the water, with which it ſhould be diluted, is as 1 to 8, 10, or 12. It would act on iron, though its proportion were greater or leſſer, though not ſo vigorouſly; but by applying a heat of 200° towards the end, 123 grains of

(B) The fixed and volatile alkalies were weighed in ether on account of their great ſolubility in water.

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of real acid would be sufficient. The air produced by this solution is entirely inflammable, and generally amounts to 115 cubic inches.

454 Quantity of inflammable air produced.

By the assistance of a strong heat, iron is also soluble in the concentrated vitriolic acid, though in smaller quantity; and instead of inflammable air, a large quantity of vitriolic air is produced, and a little sulphur is sublimed towards the end. The reason of this is, that

455 Why vitriolic air is produced by dissolving iron in concentrated oil of vitriol.

the concentrated vitriolic acid, containing much less specific fire than the dilute kind, cannot expel the phlogiston in the form of inflammable air (which absorbs a vast quantity of fire), but unites with it when further dephlegmated by heat, and thus forms both vitriolic air and sulphur. An hundred grains of iron dissolved without heat afford more than 400 of vitriol; and 100 grains of vitriol, when crystallized, contain 25 of iron, 20 of real acid, and 55 of water. When calcined nearly to redness, these crystals lose about 40 *per cent.* of water.

456 Solution of the calces of iron in vitriolic acid.

The calces of iron are soluble in the vitriolic acid according to the quantity of phlogiston they contain; the more phlogisticated being more readily soluble, and those which are dephlogisticated less so. The latter not only require more real acid for their solution, but afford only a thick liquor or magma by evaporation,

457 That of the dephlogisticated calces of iron refuses to crystallize.

instead of crystals like the others. Hence also solutions of iron, when newly made, diminish, and consequently phlogisticate, the superincumbent air by their gradual emission of phlogiston; at the same time that the calx, becoming more and more dephlogisticated, gradually falls to the bottom, unless more acid be added to keep it in solution.

458 Proportion of iron dissolved in nitrous acid.

An hundred grains of iron require for their solution in nitrous acid 142 grains of real acid, so diluted that its proportion to water should be as 1 to 13 or 14; and when this last proportion is used, the heat of a candle may be employed for a few seconds, and the access of common air prevented. Thus about 18 cubic inches of nitrous air are produced, the rest being absorbed by the solution, and no red vapours appear. But if the proportion of acid and water be as 1 to 8 or 10, a much greater quantity of metal will be dephlogisticated by the application of heat, though very

459 Quantity of nitrous air obtained from this solution.

little of it be held in solution. Thus, from 100 grains of iron Mr Kirwan has obtained 83.87 cubic inches of nitrous air; and by distilling the solution, a still greater quantity may be obtained which had been absorbed. The reason that nitrous solutions of iron or other metals

460 Why no inflammable air is here produced.

yield no inflammable air is, because this acid has less affinity to water, and more to phlogiston, than the vitriolic, and likewise contains much less fire than either that or the marine (see n° 278); and therefore unites with phlogiston, instead of barely expelling it. Hence

461 Vitriolic acid acts on iron in a much more dilute state than nitrous.

also the vitriolic acid, though united with 30 times its weight of water, will still visibly act on iron, and separate inflammable air in the temperature of 55°; whereas nitrous acid, diluted with 15 times its weight of water, has no perceptible effect on the metal in that temperature. The calces of iron, if not too much dephlogisticated, are also soluble in the nitrous acid.

462 Iron taken up by the marine acid.

Two hundred and fifteen grains of real marine acid are required for the solution of 100 grains of iron. When the proportion of water to the acid is as four to one, it effervesces rather too violently with the metal; and heat is rather prejudicial, as it volatilizes the acid. No marine air flies off; and the quantity of inflammable air is exactly the same as with diluted vitriolic acid. The calces of iron are also soluble in marine

463 Calces of iron precipitated of a reddish colour from their solution in marine acid.

acid, and may be distinguished by their reddish colour when precipitated by fixed alkalies, while the precipitates of the metal are greenish.

An hundred and eighty-three grains of real vitriolic acid are required to dissolve an hundred grains of copper; the proportion of acid to that of water being as 1 to 1.5, or at least as 1 to 1.7; and a strong heat must also be applied. Mr Kirwan says he never could dissolve

464 Proportion of copper dissolved by vitriolic acid.

the whole quantity of copper; but to dissolve a given quantity of it, a still greater heat must be employed in the proportion of 28 to 100; but this residuum also is soluble by adding more acid. Copper dephlogisticated in this manner is soluble by adding warm water to the mass.

465 Inflammable and vitriolic acid air obtained from solution of copper in vitriolic acid.

By treating 128 grains of copper in this manner, we obtain 1.1 cubic inches of inflammable air and 65 of vitriolic acid air. When inflammable air was obtained, however, our author tells us the acid was a little more aqueous. The reason why copper cannot be dephlogisticated by dilute vitriolic acid, or even by the concentrated kind without the assistance of heat, is its strong attraction to phlogiston, and the great quantity it contains.

466 Why this metal cannot be acted upon by dilute vitriolic acid.

An hundred grains of vitriol of copper contain 27 of metal, 30 of acid, and 43 of water; 28 of which last are lost by evaporation or slight calcination. An hundred grains of copper, when dissolved, afford 373 of blue vitriol.

467 Proportion of ingredients in blue vitriol.

An hundred grains of copper require 130 of pure nitrous acid for their dissolution. If the acid be so far diluted that its proportion of water be as 1 to 14, the assistance of heat will be necessary, but not otherwise. This solution affords 67½ inches of nitrous air.—The calces of copper are soluble in the nitrous

468 Quantity of copper dissolved by nitrous acid.

acid.

A like quantity of this metal requires 1190 grains of real marine acid, as well as the assistance of a moderate heat, to dissolve them; the proportion of water being as 4½ to 1. By employing a greater heat, more

469 In marine acid.

of the acid will be requisite, as much more will be dissipated: the concentrated acid acts more vigorously.—Calces of copper are likewise soluble in the marine acid, though less easily than in the nitrous.

470 Action of the vitriolic acid in tin.

The vitriolic acid dissolves tin but in small quantity; an hundred grains of the metal requiring for their solution 872 of real acid, whose proportion to water should not be less than 1 to 0.9. A strong heat is also required. When the action of the acid has ceased, some hot water should be added to the turbid solution, and the whole again heated. The metal is soluble in

471 Inflammable air obtained from the solution.

a more dilute acid, but not in such quantity.—The solution abovementioned affords 70 cubic inches of inflammable air.—The calces of tin, excepting that precipitated from marine acid by fixed alkalies, are insoluble in the vitriolic acid.

472 Tin dissolved in nitrous acid.

An hundred grains of tin require 1200 of real nitrous acid; whose proportion of water should be at least 25 to 1, and the heat employed not exceeding 60°. The quantity of air afforded by such solution is only 10 cubic inches, and it is not nitrous. The solution

lution is not permanent; for in a few days it deposites a whitish calx, and in warm weather bursts the vial. The calces of tin are insoluble in this acid.

473 **In marine acid.** Four hundred and thirteen grains of pure marine acid are required to dissolve 100 grains of tin, the proportion of water being as $4\frac{1}{7}$ to 1. The assistance of a moderate heat is also required. About 90 cubic inches of inflammable, and 10 of marine air, are afforded by the solution; but the calces of tin are nearly insoluble in this acid.

474 **Lead with vitriolic acid.** An hundred grains of lead require 600 grains of real vitriolic acid for their solution, the proportion being not less than 1 of acid to $\frac{7}{10}$ of water; and it will still be better if the quantity of water be less: for which reason, as in copper, a greater quantity of metal should be employed than what is expected to be dissolved. A strong heat is also requisite; and hot water should be added to the calcined mass, though in small quantity, as it occasions a precipitation.—

475 **Scarce soluble in dilute vitriolic acid.** This metal is also soluble, but very sparingly, in dilute vitriolic acid. Its calces are something more soluble. An hundred grains of vitriol of lead, formed by precipitation, contain 73 of lead, 17 of real acid, and 10 of water.

476 **With nitrous acid.** With spirit of nitre, 78 grains of real acid are required for the solution of 100 of lead, with the assistance of heat towards the end. The proportion of acid to that of water may be about 1 to 11 or 12. This solution produces but eight cubic inches of air, which is nitrous. The calces of the metal are soluble in this acid; but less so when much dephlogisticated. An hundred grains of minium require 81 of real acid. An hundred grains of nitrous salt of lead contain about 60 of the metal.

477 **With marine acid.** Six hundred grains of the real marine acid are required for the solution of 100 grains of lead; the specific gravity of the acid being 1.141, though more would be dissolved by a stronger acid.—The calces of lead are more soluble in this acid than the metal itself. An hundred grains of minium require 327 of real acid; but white lead is much less soluble. The same quantity of plumbum corneum, formed by precipitation, contain 72 of lead, 18 of marine acid, and 10 of water.

478 **Silver with vitriolic acid.** An hundred grains of silver require 530 of real vitriolic acid to dissolve them; the proportion of acid to water being not less than as 1 to $\frac{8}{10}$: and when such a concentrated acid is used, it acts slightly even in the temperature of 60°; but a moderate heat is required in order to procure a copious solution. The calces of silver formed by precipitation from the nitrous acid with fixed alkalies are soluble even in dilute vitriolic acid without the assistance of heat. An hundred grains of vitriol of silver, formed by precipitation, contain 74 grains of metal, about 17 of real acid, and 9 of water.

479 **With nitrous acid.** An hundred grains of the purest silver require for their solution 36 of nitrous acid, diluted with water in the proportion of one part of real acid to six of water, applying heat only when the solution is almost saturated. If the spirit be much more or much less dilute, it will not act without the assistance of heat. The last portions of silver thus taken up afford no air. Standard silver requires about 38 grains of real acid to dissolve the same proportion of it; and the solution affords 20 cubic inches of nitrous air; whereas 100 grains of silver revived from luna cornea afford about 14.

480 **Of the dissolution of silver in marine acid.** Mr Kirwan has never been able to dissolve silver in the marine acid, though Mr Bayen says he effected the dissolution of three grains and a half of it by digestion some some days with two ounces of strong spirit of salt. Newman informs us also, that leaf-silver is corroded by the concentrated marine acid. It is dissolved, however, by the dephlogisticated spirit of salt, as well as by the phlogisticated acid when reduced to a state of vapour. An hundred grains of luna cornea contain 75 of silver, 18 of acid and 7 of water.

481 **Best kind of aqua regia for dissolving gold.** Mr Kirwan found that kind of aqua regia to succeed best in the dissolution of gold, which was prepared by mixing together three parts of the real marine acid with one of the nitrous acid. Both of them ought also to be as concentrated as possible; though, when this is the case, it is almost impossible to prevent a great quantity from escaping, as a violent effervescence takes place for some time after the mixture. Aqua regia made with common salt or sal ammoniac and spirit of nitre, is much less aqueous than that proceeding from an immediate combination of both acids; and hence it is the fittest for producing crystals of gold. Very little air is produced by the solution of this metal, and the operation goes on very slow. It is, however, better promoted by allowing it sufficient time, than by applying heat.

482 **Quantity of gold taken up by aqua regia.** An hundred grains of gold require for their solution 246 grains of real acid, the two acids being in the proportion abovementioned. Though soluble in the dephlogisticated marine acid, it is only in very small quantity, unless the acid be in a state of vapour; for, in its liquid state it is too aqueous.

483 **Calces of gold soluble in the vitriolic and nitrous acids.** In vitriolic and nitrous acids it is insoluble, tho' the calces are somewhat soluble in the nitrous, more easily in the marine, but scarcely at all in the vitriolic acid.

484 **Gold cannot, according to Kirwan, be dissolved in nitrous acid.** Mr Kirwan says, that gold in its metallic state may be diffused through the concentrated nitrous acid, but not dissolved in it; contrary to the opinion of other chemists, who have affirmed that a true dissolution takes place.

485 **Mercury with vitriolic acid.** An hundred grains of mercury require for their solution 230 grains of real vitriolic acid, whose proportion to that of water is as 1 to $\frac{8}{10}$. A strong heat is also requisite, and the air produced is vitriolic. Precipitate *per se* is still less soluble.—An hundred grains of vitriol of mercury, produced by precipitation, contain 77 of metal, 19 of acid, and 4 of water.

486 **With spirit of nitre.** In spirit of nitre, 100 grains of mercury are dissolved by 28 of real acid, whose proportion to the water it contains is as 1 to 1 [illegible]. In this acid the solution takes place without heat; but it may also be dissolved in a much more dilute acid, provided heat be applied. About 12 cubic inches of air are produced when heat is not applied; but M. Lavoisier found the produce much greater. This, says Mr Kirwan, was evidently caused by his using red or yellow spirit of nitre, which already contains much phlogiston. Precipitate *per se* is much less easily dissolved in the nitrous acid, which Mr Kirwan supposes to be owing to the attraction of the aerial acid.

2d 486 **With marine acid.** The marine acid, in its common phlogisticated state, does not act on mercury, at least in its usual state of concentration; though M. Homberg, in the Paris Memoirs for the year 1700, affirms, that he dissolved it by several months digestion in this acid. When dephlogisticated, it certainly acts upon it, though very

weakly

Contents, &c. of the Salts.

weakly while in a liquid state. Precipitate *per se* is also soluble in the marine acid with the assistance of heat. An hundred grains of corrosive sublimate contain 77 of mercury, 16 of real acid, and six of water. The like quantity of mercurius dulcis contains 86 of metal and 14 of acid and water.

487 Zinc with vitriolic acid; Zinc requires for its solution an equal quantity of real vitriolic acid, whose proportion to that of water may be as 1 to 8, 10, or 12. Heat must be applied towards the end, when the saturation is almost completed. By the help of heat also this semimetal is soluble in the concentrated vitriolic acid, but a small quantity of black powder remains in all cases undissolved. An hundred cubic inches of inflammable air are produced. An hundred grains of vitriol of zinc contain 20 of zinc, 22 of acid, and 58 of water. The calces of zinc, if not exceedingly dephlogisticated, are also soluble in this acid.

488 With nitrous acid. An hundred and twenty-five grains of real nitrous acid, whose proportion to water is that of 1 to 12, are required for the solution of 100 grains of this semimetal, applying heat slightly from time to time. A concentrated acid dissolves less of the metal, as a great quantity of the menstruum escapes during the effervescence. No nitrous air can be procured, the acid being partly decomposed during the operation. The calces of zinc, if not too much dephlogisticated, are likewise dissolved by the nitrous acid.

489 Less metal dissolved by concentrated than by diluted nitrous acid.

490 With marine acid. An hundred grains of zinc, require for their dissolution 210 grains of real marine acid, the proportion of it to the water being as 1 to 9. If a more concentrated spirit of salt be made use of, a considerable part of it will be dissipated during the effervescence, and consequently more will be required for the solution. The calces of zinc are also soluble in the marine acid.

491 Bismuth scarce soluble in vitriolic acid. Only three grains of bismuth were dissolved by 200 of oil of vitriol, whose specific gravity was 1.863, though a strong heat was used at the same time. A greater quantity was indeed slightly dephlogisticated; but when the gravity of the acid was reduced to 1.200, only a single grain of the metal was dissolved by 400 of it. The calces of this semimetal are much more soluble. Four cubic inches of vitriolic air were afforded by the solution of three grains of bismuth.

492 Quantity dissolved in spirit of nitre. In spirit of nitre, 100 grains of real acid are only required to dissolve 100 grains of the metal. The proportion of water to the acid ought to be as 8 or 9 to 1; in which case a gentle heat may be applied. The solution affords 44 cubic inches of nitrous air. The calces of bismuth are also soluble in this acid.—

493 Scarce soluble in marine acids. Only three or four grains of it were dissolved by 400 of marine acid, whose specific gravity was 1.220.

2d 493 Nickel with vitriolic acid; About four grains of nickel were dissolved in an hundred of the concentrated vitriolic acid with the assistance of a strong heat; but its calces are much more soluble.—An hundred grains of nickel require for their solution 112 of real nitrous acid, whose proportion to water is as 1 to 11 or 12. The product of nitrous air is 79 inches. The calces are also soluble.

494 With nitrous acid. A moderate heat is necessary for the dissolution of the metal; but a concentrated acid acts so rapidly, that much of it is dissipated.—Only four or five grains of nickel are dissolved by 200 of spirit of salt whose specific gravity was 1.220. An acid of this degree of strength acts without the assistance of heat, though a weaker acid requires it, and dissolves still less of the metal. The calces of nickel are also soluble with difficulty in this acid.

Four hundred and fifty grains of real vitriolic acid, whose proportion to water is not less than 1 to $\frac{7}{10}$, are required for the dissolution of 100 grains of cobalt, assisted by a heat of 270° at least. A solution is obtained by pouring warm water on the dephlogisticated mass.—The calces of cobalt, however, are more soluble; so that even a dilute acid will serve.— 495 With marine acid; 496 Cobalt with vitriolic acid;

In spirit of nitre, the like quantity of cobalt requires 220 grains of real acid, whose proportion to water is as 1 to 4; giving a heat of 180 towards the end.—The calces of the metal are soluble in the nitrous acid.— 497 With spirit of nitre;

An hundred grains of spirit of salt, whose specific gravity is 1.178, dissolves, with the assistance of heat, two grains and a half of cobalt; and a greater quantity will be dissolved by an acid more highly concentrated.—The calces of cobalt are more soluble. 498 With spirit of salt;

An hundred grains of regulus of antimony require for their solution 725 grains of real vitriolic acid, whose proportion to water is as 1 to $\frac{7}{10}$, assisted by a heat of 400°. A large quantity of regulus should be put into the acid; and the resulting salt requires much water to dissolve it, as the concentrated acid lets fall much when water is added to it. A less concentrated acid will likewise dissolve this semimetal, but in smaller quantity. The calces of antimony, even diaphoretic antimony, are somewhat more soluble. 499 Regulus of antimony with vitriolic acid;

Nine hundred grains of real nitrous acid are required for the solution of 100 grains of regulus; the proportion of acid to the water of the solvent being as 1 to 12, and assisted by an heat of 110°; but the solution becomes turbid in a few days. The calces are much less soluble in this acid.— 500 With nitrous acid.

Only one grain of the regulus is dissolved by 100 of spirit of salt, whose specific gravity was 1.220, with the assistance of a slight heat; and that which is only 1.178 dissolves still less; but Mr Kirwan is of opinion that the concentrated acid would, in a long time, and by the assistance of a gentle heat, dissolve much more. The calces dissolve more easily in the marine acid. 501 Scarce soluble in the marine acid.

Eighteen grains of regulus of arsenic are dissolved in a heat of 250° by 200 grains of real vitriolic acid, whose specific gravity is 1.871. About seven of these parts crystallize on cooling, and are soluble in a large quantity of water. The calces of arsenic are more soluble in this acid.— 502 Regulus of arsenic with vitriolic acid;

An hundred and forty grains of real nitrous acid are requisite for the solution of 100 grains of regulus of arsenic; the proportion of acid to the water being as 1 to 11. The solution affords 102 cubic inches of nitrous air, the barometer being at 30 and the thermometer at 60. Calces of arsenic are likewise soluble in this acid. 503 With nitrous acid;

An hundred grains of spirit of salt, whose specific gravity is 1.220, dissolve a grain and an half of regulus of arsenic; but the marine acid, in its common state, that is, when its gravity is under 1.17, does not at all affect it. The arsenical calces are less soluble in this than in the vitriolic or nitrous acids. 504 With spirit of salt.

§ 3. *Of the Quantity of Phlogiston contained in different Substances.*

Having gone through all the various bases with which acids are usually combined, and ascertained the quantity

Quantity of Phlogiſton in different Subſtances.

quantity of different ingredients contained in the compounds reſulting from their union, we ought next to give an account of our author's experiments on phlogiſton; but as his ſentiments on that ſubject are taken notice of elſewhere, we ſhall content ourſelves with briefly mentioning the very ingenious methods by which he diſcovers the quantities of it contained in various kinds of air and in ſulphur.

505 Quantity of phlogiſton contained in nitrous air.

Having proved that inflammable air, in its concrete ſtate, and phlogiſton are the ſame thing, Mr Kirwan proceeds to eſtimate the quantity contained in nitrous air in the following manner.

"An hundred grains of filings of iron, diſſolved in a ſufficient quantity of very dilute vitriolic acid, produced, with the aſſiſtance of heat gradually applied, 155 cubic inches of inflammable air; the barometer being at 29.5, and the thermometer between 50° and 60°. Now, inflammable air and phlogiſton being the ſame thing, this quantity of inflammable air amounts to 5.42 grains of phlogiſton.—Again, 100 grains of iron diſſolved in dephlogiſticated nitrous acid, in a heat gradually applied and raiſed to the utmoſt, afford 83.87 cubic inches of nitrous air. But as this nitrous air contains nearly the whole quantity of phlogiſton which iron will part with (it being more completely dephlogiſticated by this than any other means), it follows, that 83,87 cubic inches of nitrous air contain at leaſt 5.42 grains of phlogiſton. But it may reaſonably be thought, that the whole quantity of phlogiſton which iron will part with is not expelled by the vitriolic acid, but that nitrous acid may expel and take up more of it. To try whether this was really the caſe, a quantity of green vitriol was calcined until its baſis became quite inſipid; after which two cubic inches of nitrous air were extracted from 64 grains of this ochre; and conſequently 100 grains, would yield 3.12 cubic inches of nitrous air. If 83.87 cubic inches of nitrous air contain 5.42 of phlogiſton; then 3.12 cubic inches of this air contain 0.2 of phlogiſton. The nitrous acid, therefore, extracts from 100 grains of iron two-tenths of a grain more phlogiſton than vitriolic acid does. Therefore 83.87 cubic inches of nitrous air, containing nearly the whole phlogiſton of the iron, have 5.62 of this ſubſtance. Hence 100 cubic inches of nitrous air contain 6.7 grains of phlogiſton."

2d 505 Quantity of phlogiſton in fixed air;

With regard to the quantity of phlogiſton in fixed air, after proving at length that it is compoſed of dephlogiſticated air united to the principle of inflammability, Mr Kirwan aſcertains the quantity of the latter in the following manner: "Dr Prieſtley, in the fourth volume of his Obſervations, p. 380, has ſatisfactorily proved, that nitrous air parts with as much phlogiſton to common air, as an equal bulk of inflammable does when fixed in the ſame proportion of common air. Now, when inflammable air unites with common air, its whole weight unites to it, as it contains nothing elſe but pure phlogiſton. Since, therefore, nitrous air phlogiſticates common air to the ſame degree that inflammable air does, it muſt part with a quantity of phlogiſton, equal to the weight of a volume of inflammable air, ſimilar to that of nitrous air. But 100 cubic inches of inflammable air weigh three grains and a half; therefore 100 cubic inches of nitrous air part with 3.5 grains of phlogiſton, when they communicate their phlogiſton to as much common air as will take it up. In this proceſs, however, the nitrous air does not part with the whole of the phlogiſton it contains, as appears by the red colour it conſtantly aſſumes when mixed with common or dephlogiſticated air; which colour belongs to the nitrous acid, combined with the remainder of its phlogiſton, whence the acid produced is always volatile.

"One meaſure of the pureſt dephlogiſticated air and two of nitrous air occupy but $\frac{3}{100}$ of one meaſure, as Dr Prieſtley has obſerved. Suppoſe one meaſure to contain 100 cubic inches, then the whole, very nearly, of the nitrous air will diſappear (its acid uniting to the water over which the mixture is made), and 97 cubic inches of the dephlogiſticated air, which is converted into fixed air by its union with the phlogiſton of the nitrous air; therefore 97 cubic inches of dephlogiſticated air take up all the phlogiſton which 200 cubic inches of nitrous air will part with; and this we have found to be ſeven grains: therefore a weight of fixed air equal to that of 97 cubic inches of dephlogiſticated air, and 7 of phlogiſton, will contain ſeven grains of the latter. Now, 97 cubic inches of dephlogiſticated air weigh 40.74 grains; to which adding 7, we have the whole weight of the fixed air,=47.74 grains,=83.755 cubic inches; and conſequently 100 cubic inches of fixed air contain 8.357 grains of phlogiſton, the remainder being dephlogiſticated air. An hundred grains of fixed air, therefore, contain 14.661 of phlogiſton, and 85.339 of elementary or dephlogiſticated air. Hence alſo 100 cubic inches of dephlogiſticated air are converted into fixed air by 7.2165 grains of phlogiſton, and will be then reduced to the bulk of 86.34 cubic inches.

506 In vitriolic acid air.

To find the quantity of phlogiſton in vitriolic acid air, our author purſued the following method.

1. He found the quantity of nitrous air afforded by a given weight of copper, when diſſolved in the dephlogiſticated nitrous acid, and by that means how much phlogiſton it parts with.

2. He found the quantity of copper which a given quantity of the dephlogiſticated vitriolic acid could diſſolve; and obſerved, that it could not entirely ſaturate itſelf with copper without dephlogiſticating a further quantity which it does not diſſolve.

3. He found how much it dephlogiſticates what it thoroughly diſſolves, and how much it dephlogiſticates what it barely calcines.

4. How much inflammable air a given quantity of copper affords when diſſolved in the vitriolic acid to the greateſt advantage.

5. He deducts from the whole quantity of phlogiſton expelled by the vitriolic acid the quantity of it contained in the inflammable air; the remainder ſhows the quantity of it contained in the vitriolic acid air.

The concluſion deduced from experiments, conducted after this manner is, that 100 cubic inches of vitriolic air contain 6.6 grains of phlogiſton, and 71.2 grains of acid; and 100 cubic inches of this air weighing 77.8 grains, 100 of it muſt contain 8.48 grains phlogiſton, and 91.52 of acid.

507 Quantity of phlogiſton in Sulphur.

To find the quantity of phlogiſton in ſulphur, Mr Kirwan propoſed to eſtimate that of the fixed air produced during its combuſtion. For this purpoſe he firmly tied and cemented to the open top of a glaſs bell a large bladder, deſtined to receive the air expanded by combuſtion, which generally eſcapes when this

Quantity of Phlogiston in different Substances. this precaution is not ufed. Under this bell, containing about 3000 cubic inches of air, a candle of fulphur, weighing 347 grains, was placed; its wick, which was not confumed, weighing half a grain. It
508 Proper method of burning fulphur. was fupported by a very thin concave plate of tin, to prevent the fulphur from running over during the combuftion; and both were fupported by an iron wire fixed in a fhelf in a tub of water. As foon as the fulphur began to burn with a feeble flame, it was covered with the bell, the air being fqueezed out of the bladder. The infide of the bell was foon filled with white fumes, fo that the flame could not be feen; but in about an hour after all the fumes were thoroughly fubfided, and the glafs become cold, as much water entered the bell as was equal to 87.2 cubic inches; which fpace our author concludes to have been occupied by fixed air, and which muft have contained 7.287 grains of phlogifton. The candle of fulphur being weighed was found to have loft 20.75 grains; therefore 20.75 grains of fulphur contain 7.287 of phlogifton, befides the quantity of phlogifton which remained in the vitriolic air. This air muft have amounted to $20.75-7.287=13.463$ grains, which, as already fhown, contain 1.41 grains of phlogifton. Therefore the whole quantity of phlogifton in 20.75 grains of fulphur is 8.428; of confequence 100 grains of fulphur contain 59.39 of vitriolic acid, and 40.61 of phlogifton.

509 Quantity of phlogifton in marine acid air. The quantity of phlogifton contained in marine acid air was found by the following method.—Eight grains of copper diffolved in colourlefs fpirit of falt afforded but 4.9 inches of inflammable air; but when the experiment was repeated over mercury, 91.28 cubic inches of air were obtained. Of thefe only 4.9 cubic inches were inflammable; and confequently the remainder, 86.38 inches, were marine air, weighing 56.49 grains.—Now as fpirit of falt certainly does not dephlogifticate copper more than the vitriolic acid does, it follows, that thefe 4.9 cubic inches of inflammable air, and 86.38 of marine air, do not contain more phlogifton than would be feparated from the fame quantity of copper by the vitriolic acid; and fince 100 grains of copper would yield to the vitriolic acid 4.32 grains of phlogifton, 8.5 grains of copper would yield 0.367 grains of phlogifton. This therefore is the whole quantity extracted by the marine acid, and contained in 91.28 cubic inches of air; and, deducting from this the quantity of phlogifton contained in 4.9 cubic inches of inflammable air $=0.171$ grains, the remainder, *viz.* $0.367-0.171=0.196$, is all the phlogifton that can be found in 86.38 cubic inches of marine air. Then 100 cubic inches of it contain but 0.227 of a grain of phlogifton, 65.173
510 Why marine acid acts fo weakly. grains being acid.—Hence we fee why it acts fo feebly on oils, fpirit of wine, *&c.* and why it is not diflodged from any bafis by uniting with phlogifton, as the vitriolic and nitrous acids are, its affinity to it being inconfiderable.

§ 4. *Remarks on the Doctrines of the Quantity and fpecific Gravity above delivered.*

2d 510 Mr Keir's objections to Kirwan's doctrines. To this doctrine of the fpecific gravity and quantity of acid contained in different fubftances, Mr Keir has made feveral objections. 1. Mr Kirwan fuppofes, that marine acid gas is the pure and folid marine acid divefted of all water and other matter. Its apparent drynefs in this refpect, however, is no argument that it really contains no water; for water itfelf, reduced to a ftate of vapour, poffeffes no moiftening property. There is great reafon to believe that water is a conftituent part of fome gafes, and it is certain that all of them are capable of holding it in folution. As moift materials, therefore, are employed in the preparation of marine acid air, there feems no reafon to believe, that in any way in which Mr Kirwan could obtain it, there was reafon to fuppofe it perfectly free of water; in which cafe the denfity of the acid would be greater, and its quantity fmaller than he fuppofes. Remarks on the former Doctrines.

2. A confiderable part of the denfity of the acid abforbed in the experiment, probably arofe from the condenfation which always accompanies the union of a concentrated acid with water. Mr Kirwan allows this to be the cafe with the nitrous and vitriolic acids, but thinks it too inconfiderable to deferve notice in the marine. His reafoning, however, does not appear fatisfactory, or his experiments on the fubject conclufive. He obferves, that the length of time taken up in effecting an union between the marine gas and water, is no argument againft their attracting one another ftrongly when once united; and it is certain that part of this acid gas is very quickly abforbed by water. He alfo finds fault with his accuracy in calculation; and afferts, that if matters are fairly ftated, the real denfity of the marine acid gas will be confiderably lefs than Mr Kirwan makes it.

3. A great obftacle even to an approximation towards the real denfity of the acid, arifes from the condenfation which the water, as well as the acids, muft fuffer in the procefs: and in this cafe, where a general condenfation takes place, he afks, "How fhall we determine the part of the condenfation that belongs to the water, and the part that the acid fuftains?" This, with other confiderations, makes Mr Keir "doubt of the poffibility of folving the queftion concerning the actual denfity of pure and folid acids." The inveftigation of the queftion, indeed, he does not confider as a matter of great confequence, as every ufeful application may be obtained, by firft inveftigating the comparative ftrengths of different portions of the fame acid rendered more or lefs dilute; and then by finding out the ftrength of the vitriolic, nitrous, and marine acids of known denfities, fo that they may be compared together. "Homberg (fays he) has the merit of making the firft effay towards this inveftigation. Bergman and Wenzal have fupplied the defect of Homberg, by taking into confideration the gas united with alkaline fubftances; and Mr Kirwan, by ufing determinate quantities of acid liquors of known denfities, has confiderably improved the method of Bergman: and whoever fucceeds thefe able chemifts in this inquiry, may avail himfelf greatly of their labours, particularly thofe of Mr Kirwan." He concludes with ftating the refults of the inquiries made by the chemifts abovementioned; on which he makes the following remarks.

"The difcordancy of thefe refults is very ftriking, and gives but an humiliating reprefentation of the precifion of our prefent knowledge in chemiftry. A great part of the difference arifes undoubtedly from the different views in which thefe authors confidered the drynefs or purity of the acids. Mr Kirwan, as we have feen, endeavoured to find their denfity and quantity in 3d 510 Great differences in the calculations of different authors.

Remarks on the former Doctrines.

a ftate of perfect drynefs and purity; which he fuppofed to exift in the marine acid gas: with which he compared and inferred the denfities and quantities of the nitrous and vitriolic acids, upon the fuppofition that equal quantities of thefe feveral acids are faturated by a given weight of fixed alkali. Befides the uncertainty of his principles, from which he deduces the denfity and quantity of the marine acid, his applications from thence to deduce the denfities of the pure nitrous vitriolic acids, being founded on the above fuppofition, muft partake of its defects. The alkali which he happened to fix on as the ftandard by which he compared the ftrengths of the different acid liquors, in order to determine the quantity of real acid they contained, and thence to determine their denfity in a folid ftate, was the fixed vegetable. Having found that 100 grains of his real marine acid could faturate 215 grains of this alkali, he infers, that the fame proportion is applicable to the other acids: and accordingly we find that 100 grains of each of the pure and real mineral acids are faturated by an equal quantity, *viz.* 215 grains of this alkali. But if we examine the other columns of his table, we fhall at once fee, that, in other fubftances foluble by acids, this equality does not exift; and that every fuch fubftance has a ratio peculiar to itfelf, with refpect to the proportions of thefe acids neceffary for its faturation. It is evident, therefore, that if Mr Kirwan had fixed on the mineral alkali, the volatile alkali, lime, or any other fubftance, as a ftandard, inftead of vegetable alkali, his determination of the denfities of the real vitriolic and nitrous acids would have been different; and as no reafon can be affigned why the vegetable alkali or any other fubftance fhould have the prerogative over the reft, it is obvious that there can be no fuch general ftandard, but that each fubftance poffeffes folely the capacity of determining the proportions of the feveral acids neceffary for its faturation.

"The other chemifts were contented to confider as the pure and dry acid, that which actually remains in the neutral falt, after this has been rendered as dry as poffible by expofure to a red heat: and having made their alkalies as dry as they could, they fuppofed thefe alkalies to retain the fame weight in the dried neutral falt; and that the augmentation of the weight gained by the alkali during the formation of the neutral falt fhowed the weight of the dry acid. The uncertainty which affects this method arifes from the different capacities which different neutral falts may poffefs of retaining more or lefs water, either as a conftituent part of the dry falt, or merely by the ftrength of adhefion or affinity. Neverthelefs, this method being founded folely on experiment, without any theoretical inductions, feems to furnifh fome approximation, not perhaps of the abfolute quantity of the acids in their drieft poffible ftate, but of the acids as they actually exift in thefe falts comparatively with each other. Though the difagreements between Bergman's and Wenzel's refults are little in comparifon of the difference between them and Kirwan's, yet as their experiments were made nearly in the fame manner, and upon the fame grounds, there feems to be fufficient reafon to wifh for a careful repetition of their experiments, or of others with the fame view, and lefs liable to objections.

"The only difference in the methods employed by thefe two celebrated chemifts confifted in the mode of faturation. Bergman probably ufed the common method, but Wenzel employed a very peculiar one. He added to his alkali a greater quantity of acid than was neceffary for the faturation; and after the alkali was diffolved, he added a lump of zinc, or of oyfter-fhell, in order to faturate completely the fuperfluous acid. By obferving how much of the zinc or oyfter-fhell the acid diffolved, and knowing how much of thefe fubftances was foluble in his acid by former experiments, he inferred the quantity of acid left for the faturation of the alkali. Having thus afcertained the quantity neceffary to faturate the alkali, he mixed together the proper proportions of thefe, and formed his neutral falt by evaporating the mixture and drying the falt with a red heat. Perhaps the difference in the refults obtained by thefe two chemifts might arife from their different modes of faturation. The common method of afcertaining the point of faturation by means of litmus or other blue vegetable juices, appears fufficiently exact, is fimpler, and therefore preferable to that ufed by Wenzel.

"The ftandard for comparing the ftrengths of acids, and likewife of alkalies with one another, may be either an acid or an alkaline fubftance; and if we had one of each, the proportion of whofe quantities requifite for their mutual faturation were well afcertained, the conveniency in making the experiments would be obvious, and the certainty greater. Alkaline, and the earthy fubftances that are foluble in acids, are feldom pure enough for this purpofe. They generally contain quantities, which are not conftant, of fixed air, filiceous earth, magnefia, neutral falts, and inflammable matter, which render any of thofe that are commonly met with unfit for the purpofe without a very fkilful and careful purification. The chemifts who have made experiments to determine the proportions of acids and alkalies requifite for each other's faturation, have fcarcely been explicit enough in explaining the means of purifying the alkalies which they employed: for thofe in commerce are quite uncertain in ftrength and purity: and as to the general rules for making allowances for any heterogeneous fubftances they may contain, they are quite inapplicable to delicate experiments. No other method feems proper for afcertaining the purity of alkalies but that of cryftallization: of which both the vegetable and mineral alkalies are fufceptible, efpecially the latter, which on account of its being more eafily reducible into cryftals, is therefore preferable. Thefe alkaline cryftals, however, are not fit to be ufed as a ftandard, becaufe they either are apt to be fufficiently dried, or, upon expofure to air, to lofe a part of the water of their cryftallization, and to fall into powder. Even if they fhould be taken, as is poffible with due care, at the exact ftate of dry but entire cryftals, another uncertainty arifes from a property which feems to be common to them all, namely, that of retaining a greater or fmaller quantity of water, according to the degree of heat in which they were cryftallized; the colder the weather the greater quantity of water entering into the compofition of the cryftals. It feems poffible, however, to make a pretty accurate ftandard of mineral alkali in the following manner: Let the alkali be purified by repeated folution

4th 510 Mr Keir's method of preparing an alkaline ftandard.

Remarks on the former Doctrines.

tion and cryſtallization, uſing only ſuch as are formed firſt, and rejecting the remaining liquors. Let the pure cryſtals be expoſed to a dry air until they have completely effloreſced or fallen into a dry white powder; which alteration may be facilitated by bruiſing the cryſtals and changing the ſurface of the powder. Let this powder be then expoſed for a certain and determinate time to a conſtant heat, as that of boiling water for 12 hours; letting the ſurface expoſed be in ſome given proportion, ſuppoſe of a ſquare inch to an ounce of the powder of cryſtals, and let it be ſtirred every two hours. When thus dried, let them be put while hot into a bottle, and well ſtopped. This powder I have found to be an uniform and conſtant ſtandard for aſcertaining the ſtrength of acids; and alſo, by compariſon by means of acids, of other alkaline ſubſtances."

With regard to an acid ſtandard, our author recommends oil of vitriol; which, he ſays, as it comes from the hands of the Britiſh manufacturers, is of the ſpecific gravity of about 1.846, but ſoon becomes weaker, unleſs carefully kept from the external air; and in general he rates it at 1.844. One part of this acid mixed with nine of water, is of a very convenient ſtrength for uſe; and as every ten grains of the mixture contain one of the ſtandard acid, the computations are thus rendered eaſy: and by theſe ſtandards, the ſtrength of all acids, alkalies, and ſubſtances ſoluble in acids, may be meaſured and compared together.

5th 510 His method of finding the ſpecific gravity of different liquors.

To determine the ſpecific gravity of liquors with accuracy, our author recommends the method of weighing them in a phial fitted with a glaſs-ſtopper, which can only enter a certain length into the neck. In this way, he obſerves, no other inconvenience can enſue than the ſlight one, that the glaſs-ſtopper, by very frequent uſe, is apt to wear itſelf and the neck of the phial alſo; ſo that after a great number of experiments, it will at laſt diminiſh, in ſome meaſure, the capacity of the phial itſelf. This, however, is but very trifling, and may be corrected at any time. Mr Keir has beſides found, that after ſome hundreds of experiments, the error amounted only to one quarter of a grain in 101 grains.

"The methods hitherto practiſed (ſays he) for aſcertaining the quantities of acids and alkalies contained in neutral ſalts, ſeem to be liable to ſeveral objections beſides thoſe abovementioned, ariſing from the different proportions of water remaining in a neutral ſalt, after expoſure to a red-heat, which heat is alſo very indefinite. In boiling the ſaturated mixture of acid and alkali to dryneſs, and afterwards in expoſing this ſalt to a red-heat, it has been ſuppoſed that nothing but water is expelled; and ſome chemiſts, who have given the reſults, have alſo determined the weight of the alkali which enters into the neutral mixture, by evaporating to dryneſs an equal quantity of the alkaline ſolution which had been employed in the ſaturation, and weighing the dry ſolution, on the ſuppoſition that nothing is expelled but water. It is certain, however, that in the evaporation both of alkalies and neutral ſalts, a conſiderable portion of the ſaline matter is elevated towards the end, when the liquor becomes concentrated and acquires a degree of heat conſiderably above that of boiling water. The following method appears beſt for determining the relative quantities of acid and alkali, or other ſubſtance exiſting in neutral ſalts.

"To a given number of grains, ſuppoſe 100 of the ſtandard vitriolic acid, or to a proportionable quantity of any other acid, add as much of the alkali or other ſoluble ſubſtance as is requiſite for the ſaturation, and note the quantity required, which ſuppoſe to be 150 grains. We have thus a ſolution of the neutral ſalt, which is the object of the experiment; the quantities of acid and baſis contained in which are known, and the general proportion of the quantity of the acid to its baſis in the neutral ſalt determined, *viz.* as 100 to 150. The next thing to be diſcovered is the weight of the dry neutral ſalt contained in this ſolution, in order to know the proportion of the dry neutral ſalt to its acid and baſis. For this purpoſe, let a given quantity of the ſame neutral ſalt, either in the ſtate of cryſtals or dried to any given degree, be diſſolved in water. Let this ſolution be brought to the ſame denſity as the former, by adding water to the heavier of the two: then, by knowing the weight of each ſolution, and the quantity of dry neutral ſalt which was actually diſſolved in one of them, the quantity contained in the other may be deduced; and thence the quantities of ſtandard acid, or of other acid proportioned to it, and of the alkali employed, or other ſoluble ſubſtance contained in a given quantity of the neutral ſalt, are determined; alſo the quantity of water contained in the neutral ſalt, that is greater or leſs than what is contained in the quantity of acid employed, will be known, over and above any water that may have been contained in the alkali or other baſis of the neutral ſalt; the quantity of which water, if any, cannot be determined.

"By this method may be aſcertained the proportion of the acid, of the baſis, and of the neutral ſalt, to each other; not indeed the quantity of acid and of alkali deprived of all water, but the quantity of acid, equal in intenſity of acidity to a known portion of the ſtandard acid; and alſo the quantity of ſuch alkali or other ſoluble ſubſtance as was employed; the relative ſtrength of which is known from its ratio to the ſtandard acid."

6th 510 Objection to Kirwan's calculation of the quantity of phlogiſton in ſulphur.

The tranſlator of Wiegleb's Syſtem of Chemiſtry totally diſagrees with Mr Kirwan's calculation of the quantity of phlogiſton contained in ſulphur; but as his objection ſeems to ariſe rather from an inclination to the antiphlogiſtic doctrine that a real diſcuſſion of the ſubject, this can have but little weight. It is poſſible indeed that Mr Kirwan may have over-rated the quantity of phlogiſton this ſubſtance contains, which is indeed larger than that allowed by other chemiſts. "Brandt (ſays the tranſlator), who has been moſt generally followed, reckons it only at $\frac{1}{12}$; and it has always appeared to me, that the weight of phlogiſton in ſulphur is almoſt infinitely ſmall." His objection proceeds on a maxim which he thinks he has demonſtrated, *viz.* that ſulphur is compoſed, not of the vitriolic acid and phlogiſton, but of the *baſe* of vitriolic acid and phlogiſton. No experiments hitherto made, however, have been able to ſhow this baſe diſtinct from the acid; nor have we any reaſon to ſuppoſe that the increaſe of weight in the vitriolic acid above the ſulphur from

Earths. from which it is produced, arises from any thing besides the accession of mere water, which the air parts with during the combustion. Hence, if the sulphur is burnt in a very moist air, the quantity of acid obtained will be four or five times the weight of the sulphur.

SECT. IV. *Earths.*

THESE are divided into five classes: 1. Absorbent, alkaline, or calcareous earths: 2. Argillaceous earths or clay: 3. The flinty: 4. The fusible earths: and, 5. The talks.

1. The first class comprehends all those that are capable of being converted into lime. They are found of various degrees of hardness; but none of them are capable of totally resisting the edge of a knife, or striking fire with steel. They are found to consist of a very friable earth, joined with a large quantity of air and some water. They effervesce with an acid when poured on them; by which they are distinguished from all other kinds of earth, except the argillaceous. When calcined by a strong fire, they part with the water and air which they contained, and then acquire a great degree of causticity, lose their power of effervescing with acids, and become what is called

511 Quicklime. *quicklime*. They are soluble in acids, but not equally so in all. The vitriolic and tartareous acids form compounds with them very difficultly soluble; the *selenites*, formed by the vitriolic acid and calcareous earth, requiring, according to Mr Beaumé, an ounce of water to dissolve a single grain of it. The solubility of the tartareous selenite hath not yet been determined.—With the other mineral acids, the calcareous earths become easily soluble; and by proper management form concretes which appear luminous in the dark, and are called *phosphori*.

512 Argillaceous. 2. The argillaceous earths differ from the calcareous, in not being convertible into quicklime. When mixed into a paste with water, and exposed to the fire, they shrink remarkably, crack in many places, and become excessively hard. By being gently dried in the open air before they are turned, they do not crack, and thus may be formed into vessels of any shape. Of this kind of earth are formed all the brown sort of earthen ware. The purest kind of argillaceous earth naturally found, is that whereof tobacco-pipes are made.

All the argillaceous earths are soluble in acids. With the vitriolic they dissolve into a gelatinous tough liquor very difficultly crystallizable; but which, on the addition of some fixed or volatile alkali, may be shot into crystals of the salt called *alum*. With the other acids they form astringent salts of a similar nature.

The attraction between the argillaceous earths and acids is very weak, yielding not only to alkaline salts both fixed and volatile, but even to some metals, particularly iron; but these earths have as yet been but little the subject of chemical examination in this way. They have a remarkable property of absorbing the colouring matter of cochineal, Brasil-wood, *&c.* as have also the calces of some metals.

Both the calcareous and argillaceous, and indeed all earths when pure, resist the utmost violence of fire; but when mixed together will readily melt, especially if in contact with the burning fuel. Dr Lewis having made covers to some crucibles of clay and chalk mixed together, found that they melted into a yellow glass, before the mixtures in the crucibles were fused in the least. But though they melted thus readily when in contact with the fuel, it was with great difficulty he could bring them to a transparent glass when put into a crucible.

The other species of earths, *viz.* the flinty, fusible, and talky, being no other way the subjects of chemistry than as they are subservient to the making of glass, all that can be said of them will most properly come under that article. For their different species, see MINERALOGY.

513 Anomalous earths. Besides the abovementioned species of earths, there are others which may be called *anomalous*, as having some resemblance of the calcareous and argillaceous, and yet being essentially different from them. These are the white earth called *magnesia alba*, the earth of burnt vegetables, and that produced from burning animal substances.

514 Magnesia. Magnesia alba was at first prepared from the thick liquor remaining after the crystallization of nitre; and is now found to be contained in the liquor called *bittern*, which is left after the separation of common salt from sea-water. In the former case it was united with the nitrous, in the latter with the vitriolic, acid. It is also found naturally in the soft kind of stone called *steatites* or "soap-stone;" and in the concrete used for taking spots out of cloaths, called *French chalk*. It differs from the calcareous earths, in not acquiring any causticity when deprived of its air, of which it contains so large a quantity as to lose two-thirds of its weight when calcined. From the argillaceous it differs in not burning hard when mixed with water, nor forming a tough ductile paste. It is easily soluble in all the acids, even the vitriolic; with which it forms the bitter purging salt commonly called *Epsom salt*, from its being first discovered in the waters of Epsom. With all the other acids it likewise forms purgative compounds, which are either very difficultly or not at all crystallizable.—Like other pure earths, it cannot be melted by itself; but, on proper additions, runs into a beautiful green glass.

515 Vegetable and animal earths. The earth of burnt vegetables is thought by Dr Lewis to be the same with magnesia alba; but on trying the common wood ashes, they were found to be very different. This kind of earth is fusible, by reason of the alkaline salts contained in it. Animal earth is both very difficult of solution in acids, and impossible to be melted in the strongest fire. It dissolves, however, in acid liquors, though slowly; but the nature of the compounds formed by such an union are as yet unknown. The softer parts of animals, such as blood, flesh, *&c.* are said to yield a more soluble earth than the others. Animal earth has lately been supposed to be compounded of calcareous earth and phosphoric acid; but this opinion is shown to be erroneous under the article BONES. The phosphoric acid produced from these, is with reason supposed to be only the vitriolic acid changed.

SECT. V. *Inflammable Substances.*

516 Phenomena on burning. THESE comprehend all vegetable, animal, and some mineral substances. They are distinguished from all others,

Inflammable Subſtances. others, by emitting a groſs thick ſmoke and flame, when a certain degree of heat is applied. To this, however, ſpirit of wine and all preparations from it are exceptions. They burn without the leaſt ſmoke; and if a glaſs bell is held over the burning ſpirit, no ſoot is formed, only a quantity of water is found condenſed on its ſides. Even the groſſer oils, if ſlowly burnt with a very ſmall flame, will yield no ſoot; and an exceeding great quantity of water, fully equal in weight and bulk to the oil employed, may be obtained from them. We can ſcarcely, however, credit, that ſo great a quantity of water comes from the oil; as this would be a real tranſmutation; and we know that, beſides water, the oils contain alſo ſome quantity of fixed air, as well as earth. It is probable, therefore, that, as it is impoſſible to ſuſtain flame without a decompoſition of that part of the air which ruſhes in to ſupport it, part of the water in this caſe comes from the air, which always contains moiſture in abundance.

Inflammable matters, on being burnt, generally leave behind a ſmall quantity of earthy matter called *aſhes*; but to this, ſpirit of wine, camphor, the more volatile oils, and the mineral oil called *naptha*, are exceptions.

517 On diſtillation. Vegetable ſubſtances, when diſtilled in cloſe veſſels, give out a quantity of air, ſome acid, and an empyreumatic oil, leaving behind a black ſpongy maſs called *charcoal*. To this too there are a few exceptions, *viz.* ſpirit of wine, and the preparations from it, camphor, and perhaps ſome of the more volatile oils, or naphtha. Animal ſubſtances yield only a very fetid empyreumatic oil, and volatile alkali.

518 Treated with different acids. In general, all inflammable matters are acted upon with ſome violence by the vitriolic and nitrous acids, excepting only camphor and naphtha. With the vitriolic acid, when in a liquid ſtate, they render it volatile and ſulphureous; if in a dry ſtate, they form actual ſulphur. With the nitrous, they firſt impart a high colour and great degree of volatility to the acid; then a violent flame enſues, if the matter is attempted to be dried. With ſpirit of wine the effects are conſiderably different; and very volatile compounds are formed, which are called *ether*, on account of their exceeding great diſpoſition to riſe in vapour. Similar compounds are likewiſe produced, but with more difficulty, from the marine acid and concentrated vinegar. The ſal ſedativus of borax mixes with ſpirit of wine, and cauſes it burn with a green flame; but does not ſeem to produce any other change upon it. How the acid of phoſphorus and of ants act upon ſpirit of wine, is not exactly known; but that of tartar by digeſtion with it, is converted into the acetous acid. With any other inflammable matter, the phoſphorine acid reproduces phoſphorus.

519 Singular productions. There are two ſingularities obſerved among the inflammable ſubſtances. One is that bituminous matter called *amber*, which yields a volatile ſalt of an acid nature on diſtillation: When combined with alkalies, this acid is found to yield compounds ſimilar to thoſe made with the acetous acid and alkali. The other is, that gum called *benzoin*, which is uſed as a perfume, and yields by ſublimation a kind of volatile ſalt in fine ſhining cryſtals like ſmall needles, and of a moſt grateful odour. Theſe diſſolve very readily in ſpirit of wine; but not at all in water, unleſs it is made very hot: ſo that they ſeem to contain more oily than ſaline matter. Neither the nature of theſe flowers, however, nor that of the ſalt of amber, is fully known.

Sect. VI. *Metalline Subſtances.*

Metalline Subſtances. These are diſtinguiſhed from all other bodies by their great ſpecific gravity, exceeding that of the moſt denſe and compact ſtones. The heavieſt of the latter do not exceed the ſpecific gravity of water in a greater proportion than that of 4 to 1; but tin, the lighteſt of all the metals, exceeds the ſpecific gravity of water in the proportion of 7 to 1. They are alſo the moſt opaque of all known bodies, and reflect the rays of light moſt powerfully.

520 Metals ſoluble in acids. Metallic bodies poſſeſs the quality of diſſolving in and uniting with acid ſalts, in common with earths and alkalies; but, in general, their union is leſs perfect, and they are more eaſily ſeparable. They effervеſce with acids, as well as calcareous earths and alkalies; but their effervеſcence is attended with very different appearances. In the effervеſcence of acids with alkalies, or with calcareous earths, there is a diſcharge of the fluid called *fixed air*, which is ſo far from being inflammable, that it will immediately extinguiſh a candle or other ſmall flame immerſed in it. The mixture alſo is notably diminiſhed in weight. When a metallic ſubſtance is diſſolved in an acid, the weight of the mixture is never very much diminiſhed, and ſometimes it is increaſed. Thus, an ounce of quickſilver being ſlowly dropped into as much aquafortis as was ſufficient to diſſolve it, and the ſolution managed ſo as to take up almoſt a whole day, the whole was found to have gained ſeven grains. There is alſo a remarkable difference between the nature of the vapour diſcharged from metals and that from alkalies; the former, in moſt caſes, taking fire and exploding with violence; the latter, as already obſerved, extinguiſhing flame.

521 Their compoſition. The metallic ſubſtances, at leaſt ſuch as we are able to decompound, are all compoſed of a certain kind of earth, and the inflammable principle called *phlogiſton*. The earthy part by itſelf, in whatever way it is procured goes by the name of *calx*. The other principle has already been proved to be the ſame with charcoal.

522 Calcination and revivification. When theſe two principles are ſeparated from one another, the metal is then ſaid to be *calcined*. The calx being mixed with any inflammable ſubſtance, ſuch as powdered charcoal, and urged with a ſtrong fire melts into metal again; and it is then ſaid to be *reduced*, or revivificated: and this takes place whether the metal has been reduced to a calx by diſſolution in an acid or by being expoſed to a violent fire. If, however, the calcination by fire has been very violent and long continued, the calx will not then ſo readily unite with the phlogiſton of the charcoal, and the reduction will be performed with more difficulty. Whether, by this means, *viz.* a long continued and violent calcination, metallic earths might entirely loſe their property of combining with phlogiſton, and be changed into thoſe of another kind, deſerves well to be inquired into.

523 Calcination and increaſe of weight by acids. When a metallic ſubſtance is diſſolved in any kind of acid, and an alkali or calcareous earth not deprived of its fixed air is added, the alkali will immediately be attracted by the acid, at the ſame time that the fixed

Metalline Substances. ed air contained in the alkali is disengaged, and the calx of the metal, having now no acid to keep it dissolved, immediately joins with the fixed air of the alkali, and falls to the bottom. Something similar to this happens when metals are calcined by fire. In this case there is a continual decomposition of the air which enters the fire; and the fixed air contained in it, being, by this decomposition, set loose, combines with the calx; whence, in both cases, there is a considerable increase of weight. If the air is excluded from a metal, it cannot be calcined even by the most violent fire.

524
Reason of the increase of weights in metalline calces.

When a metal is precipitated by a mild alkali, or by an uncalcined calcareous earth, the reason of the increase of weight is very evident; namely, the adhesion of the fixed air to the metalline calx: but, though it is not so much increased when precipitated by caustic alkali, or by quicklime, there is nevertheless a very evident increase, which is not so easily accounted for. M. Lavoisier has mentioned some experiments made on mercury and iron dissolved in aquafortis, which deserve to be taken notice of, as in a great measure accounting for the phenomenon already mentioned of the solution of metalline substances gaining an addition of weight; and likewise show the proportion of increase of weight with the mild, or calcined calcareous earth.

525
M. Lavoisier's experiments.

"Exactly 12 ounces of quicksilver (says he) were put into a matrass, and 12 ounces of spirit of nitre poured on it. Immediately a spontaneous effervescence ensued, attended with heat. The red vapours of the nitrous acid arose from the mixture, and the liquor assumed a greenish colour. I did not wait till the solution was entirely accomplished before I weighed it; it had lost one drachm 18 grains. Three hours after, the mercury was nearly all dissolved: but having again weighed the solution, I was much astonished to perceive that it had increased instead of being diminished in weight; and that the loss, which was one drachm 18 grains at first, was now only 54 grains. The next day the solution of the mercury was entirely finished, and the loss of weight reduced to 18 grains; so that in 12 hours the solution, though confined in a narrow necked matrass, had acquired an augmentation in weight of one drachm. I added some distilled water to my solution, to prevent it from crystallizing; the total weight of it was then found to be 48 ounces 1 drachm and 18 grains.

"I weighed separately, in two vessels, 8 ounces 15 grains of the above solution, each of which portions, according to the preceding experiment, ought to contain 2 ounces of nitrous acid and 2 ounces of quicksilver. On the other side I prepared 6 drachms 36 grains of chalk, and 4 drachms 36 grains of lime; these proportions having been found by former experiments just necessary to saturate two ounces of nitrous acid. I put the chalk in the one vessel, and the lime in the other.

"An effervescence attended the precipitation by chalk, but without heat; the mercury precipitated in a light yellow powder, at the same time the chalk was dissolved in the nitrous acid. The precipitation by the lime was effected without effervescence, but with heat; the mercury was precipitated in a brownish powder. When the precipitates were well subsided, I decanted off the liquors from them, and carefully edulcorated them. After which, I caused them to be dried in a heat nearly equal to that in which mercury boils.

"The precipitate by the chalk weighed 2 ounces 2 drachms 45 grains; that by the lime weighed 2 ounces 1 drachm 45 grains.

"Sixteen ounces of the nitrous acid, the same as employed in the former experiments, were placed in a matrass, and some iron filings gradually added. The effervescence was brisk, attended with great heat, red vapours, and a very rapid discharge of elastic fluid: the quantity of iron necessary to attain the point of saturation was 2 ounces 4 drachms; after which, the loss of weight was found to be 4 drachms 19 grains. As the solution was turbid, I added as much distilled water as made the whole weight of the solution to be exactly 6 pounds.

"I took two portions, each weighing 12 ounces of the above solution, and containing 2 ounces of nitrous acid, and 2 drachms 36 grains of iron filings. I placed them in two separate vessels. To one were added 6 drachms 36 grains of chalk; and to the other 4 drachms 36 grains of slacked lime, being the quantities necessary to saturate the acid.

"The precipitation was effected by the chalk with effervescence and tumefaction, that by the lime without either effervescence or heat. Each precipitate was a yellow brown rust of iron. They were washed in several parcels of distilled water, and then dried in an heat somewhat superior to that used in the last experiment.

"The precipitate by the chalk, when dried, was a greyish rust of iron, inclining even to white by veins. It weighed 6 drachms 35 grains. That by the lime was rather yellower, and weighed 4 drachms 69 grains.

526
Consequences from his experiments;

"The result of these experiments (says M. Lavoisier) are, 1. That iron and mercury dissolved in the nitrous acid acquire a remarkable increase of weight, whether they be precipitated by chalk or by lime. 2. That this increase is greater in respect to iron than mercury. 3. That one reason for thinking that the elastic fluid contributes to this augmentation is, that it is constantly greater when an earth is employed saturated with elastic fluid, such as chalk, than when an earth is used which has been deprived of it, as lime. 4. That it is probable that the increase of weight which is experienced in the precipitation of lime, although not so great as that by chalk, proceeds in part from a portion of the elastic fluid which remains united to the lime, and which could not be separated by the calcination."

527
Not well founded.

But though we are naturally enough inclined to think that the increase of weight in the precipitates formed by lime proceeded from some quantity of elastic fluid or fixed air which remained combined with the lime, it is by far too great to be accounted for in this way, even according to the experiments mentioned by M. Lavoisier himself, and which, from the manner in which they are told, appear to have been performed with the greatest accuracy. He found, that 1 ounce 5 drachms and 36 grains of slaked lime contained 3 drachms and 3 quarters of a grain of water,

 and

Metalline Substances.

and only 16 grains and an half of elastic fluid were separable from it. In the experiments above related, where only 4 drachms and 36 grains were employed, the quantity of elastic fluid could not exceed 6 or 8 grains. Yet the calx was increased in mercury by no less than 105 grains, and in iron by 203 grains; a quantity quite unaccountable from the elastic fluid or fixed air which we can suppose to be contained in the lime made use of. It is much more probable, that the increased weight of metallic precipitates, formed by lime, arises from an adhesion of part of the acid.

530 What metals are calcinable, & with what degrees of heat.

Metals are found to be compounded of a kind of earth mixed with the inflammable principle or phlogiston; and by a dissipation of the latter, all metallic bodies, gold, silver, and platina excepted, are capable of being reduced to a calx, but very different degrees of heat are required for calcining them. Lead and tin begin to calcine as soon as they are melted, long before they are made red-hot. The same happens to the semimetals bismuth and zinc; the latter indeed being combustible, cannot bear a greater heat in open vessels than that which is barely sufficient to melt it. Iron and copper require a red heat to calcine them; though the former may be made partly to calcine by being frequently wetted in a degree of heat considerably below that which is sufficient to make it red.

541 Rusting of metals

Most metals undergo a kind of spontaneous calcination in the open air, which is called their *rusting*; and which has given occasion to various conjectures. But M. Lavoisier has shown, that this arises from the fixable part of the atmosphere attaching itself to their earthy part, and discharging the phlogiston. According to him, no metallic body can rust but where there is an absorption of air; and consequently metals can be but imperfectly rusted when kept under a receiver.

542 Fusibility of metallic compounds.

If two metals are mixed together, the compound generally turns out more fusible than either of them was before the mixture. There are indeed great differences in the degrees of heat requisite to melt them. Thus, lead and tin melt below that degree of heat which is required to make quicksilver or linseed-oil boil. Silver requires a full red heat, gold a low white heat, copper a full white, and iron an extreme white heat, to make it melt. The semimetal called bismuth melts at about 460° of Fahrenheit's thermometer, and tin at about 422°. When mixed in equal quantities, the compound melted at 283°. When the tin was double the bismuth, it required 334° to melt it; with eight times more tin than bismuth, it did not melt under 392°. If to this compound lead is added, which by itself melts in about 540°, the fusibility is surprisingly increased. Mr Homberg proposed for an anatomical injection a compound of lead, tin, and bismuth, in equal parts; which he tells us keeps in fusion with a heat so moderate that it will not singe paper. Sir Isaac Newton contrived a mixture of the abovementioned metallic substances, in such proportions that it melted and kept fluid in a heat still smaller, not much exceeding that of boiling water. A compound of two parts of lead, three parts of tin, and five of bismuth, did but just stiffen at that very heat, and so would have melted with very little more; and when the lead, tin, and bismuth, were to one another in the proportions of 1, 4, and 5, the compound melted in 246°. We have seen, however, a piece of metal compounded of these three, the proportions unknown, which melted, and even underwent a slight degree of calcination, in boiling water, and barely stiffened in a degree of heat so gentle that the hand could almost bear it.

543 Great fusibility of compounds of tin and bismuth.

544 One fusible by the heat of boiling water.

545 Solubility of metals increased by calcination.

A slight degree of calcination seems to give the acids a greater power over metallic substances; a greater makes them less soluble; and if long and violently calcined, they are not acted upon by acids at all. Of all the acids, the marine has the greatest attraction for metallic calces, and volatilizes almost every one of them.

546 Effects of sulphur on metals.

Sulphur readily unites with most metals, destroys their malleability, and even entirely dissolves them. On gold and platina, however, it has no effect, till united with a fixed alkaline salt, when it forms the compound called *hepar sulphuris*; which is a very powerful solvent, and will make even gold and platina themselves soluble in water, so as to pass the filter. This preparation is thought to be the means by which Moses dissolved and gave the Israelites to drink the golden calf which they had idolatrously set up.

When a metal is dissolved in an acid, it may be precipitated, not only by means of calcareous earth and alkalies, but also by some other metals; for acids do not attract all metals with equal strength; and it is remarkable, that when a metal is precipitated by another, the precipitate is not found in a calcined state, but in a metallic one. The reason of this is, that the precipitating metal attracts the phlogiston which is expelled from that which is dissolving, and immediately unites with it, so as to appear in its proper form. The various degrees of attraction which acids have for the different metals is not as yet fully determined. The best authenticated are mentioned in the Table of Affinities or elective attractions (Sect. IX.)

547 Division into metals and semi-metals.

Metalline substances are divided into metals and semimetals. The metals which are distinguished from the semimetallic substances by their malleability or stretching under the hammer, are in number seven; gold, silver, copper, iron, lead, tin, and platina. To these is added quicksilver; which Mr Brown's experiments have shown to be a real malleable metal, as well as others, but requiring so little heat to keep it in fusion, that it is always found in a liquid state. The semimetals are bismuth or tin-glass, zinc, regulus of antimony, and cobalt, nickel, and arsenic. This last substance is now discovered to be compounded of an acid of a peculiar kind and phlogiston; and as the quantity of the latter is great or small, the arsenic assumes either a metallic or saline form. It likewise unites with sulphur, with which it forms a compound of a red or yellow colour, according as more or less sulphur is used. This compound is easily fusible; though the arsenic, by itself, is so volatile as to go all off in vapour rather than melt. In common with the salts, it possesses the properties of dissolving in water, and uniting itself to alkalies. Water will dissolve about $\frac{1}{80}$ of its weight of pure arsenic; but if arsenic is boiled in a strong alkaline lixivium, a much greater proportion will be dissolved. Indeed strong alkaline lixivia will dissolve

548 Properties of arsenic.

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Chemical Characters or Symbols

△ *Fire*	*Regulus of*	c. *Caustic vol. Alkali*	*A Powder*
🜁 *Air*	*Antimony*	*Potash*	*Ashes*
▽ *Water*	*Arsenic*	*Acids*	B *A Bath*
🜃 *Earth*	*Regulus of Arsenic*	*Vinegar*	B.M; M.B; *Water bath*
f.🜁 *Fixable Air*	K; *Cobalt*	*Vitriolic Acid*	A.B. *Sand bath*
m.🜁 *Mephitic Air*	N. *Nickel*	*Nitrous Acid*	V.B. *Vapor bath*
Clay	S.M. *Metallic Substances*	*Marine Acid*	*An Hour*
Gypsum	C. *Calx*	A.F. Æ. *Aquafortis*	*A Day*
Calcareous Earth	*Orpiment*	R; Æ; *Aqua Regia*	*A Night*
C.V; *Quicklime*	*Cinnabar*	*Vol. Sulphureous Acid*	*A Month*
Vitrifiable or	L.C. *Lapis Calaminaris*	*Phosphoric Acid*	aaa; *Amalgam*
Siliceous Earths	*Tutty*	V *Wine*	*To Distill*
Fluors or	*Vitriol*	*Spirit of Wine*	*To Sublime*
Fusible Earths	*Sea Salt*	R *Rectified*	*To Precipitate*
X *Talk*	*Sal Gem*	Æ *Ether*	*A Retort*
M.🜃 *Magnesia*	*Nitre*	*Lime Water*	XX. *An Alembic*
A🜃; *Earth of Alum*	*Borax*	*Urine*	*A Crucible*
∴ *Sand*	S S *Sedative Salt*	*Oil*	S.S.S. *Stratum*
☉ *Gold*	*Sal Ammoniac*	△.E. *Essential Oil*	*Super Stratum*
☽; *Silver*	*Allum*	*Fixed Oil*	C.C. *Cornu Cervi*
♀ *Copper*	*Tartar*	*Sulphur*	*Hartshorn*
♃ *Tin*	*Alkali*	*Hepar of Sulphur*	*A Bottle*
♄ *Lead*	*Fixed Alkali*	*Phosphorus*	gr.i. *A Grain*
☿ *Mercury*	*Volatile Alkali*	*Phlogiston*	℈i. *A Scruple*
♂ *Iron*	m. *Mild fixed Alkali*	◇ *Soap*	ʒi. *A Dram*
Zinc	c. *Caustic fixed*	*Verdigrise*	℥i. *An Ounce*
B:W? *Bismuth*	*Alkali*	*Glass*	℔i *A Pound*
♁ *Antimony*	m. *Mild vol. Alkali*	*Caput Mortuum*	dwt.i. *A Penny weight*

Scot Philad.

Waters, &c. solve a part of almost every metalline substance, except gold, silver, and platina; but, excepting copper, which may be formed into crystals by means of the volatile alkali, none of them will assume a crystalline form when united with alkalies. Arsenic, on the contrary, unites very readily with fixed alkalies, and shoots with them into a neutral salt. If it is mixed with nitre, it unites itself to the alkaline basis of that salt, and expels the acid in very volatile fumes, which are difficultly condensed into a blue liquor. The reason of this is the great attraction between the nitrous acid and phlogiston, which are always disposed to unite when a proper degree of heat is applied. Was the phlogiston contained in large quantity in the arsenic, and the heat sufficiently great, a violent deflagration would ensue; but as the acid of arsenic attracts the alkaline part of the nitre, at the same time that the nitrous acid attracts the phlogiston, a double decomposition ensues, in a less degree of heat than would otherwise be necessary; and the nitrous acid arises in a very volatile state, as it always is when combined with phlogiston, which is the occasion of the blueness in aquafortis so produced. The arsenic is also decomposed by being deprived of its proper quantity of phlogiston; in consequence of which its acid attaches itself to the fixed alkali of the nitre, and forms a neutral arsenical salt. For the extraction of metallic substances from their ores, and the various methods of refining them, see METALLURGY.

SECT. VII. *Waters.*

THE pure element of water, like that of fire, is so much an *agent* in most chemical operations, as to be itself very little the *object* of practical chemistry. Some late experiments, however, have shown that this fluid really consists, in part at least, of phlogiston, and an invisible substance which forms the basis of pure air: and consequently water is generated in the deflagration of dephlogisticated air; but as the basis of the former cannot be perceived by itself, we can as yet say nothing about it. Waters, therefore, can only be the objects of chemistry, in consequence of the impurities they contain: and as these impurities are most commonly of the saline kind, it is impossible that any general theory can be given of waters, distinct from that of the salts contained in them; which all depend on the general properties belonging to salts, and which we have already mentioned. Any thing that can be said with regard to waters, then, must be postponed to the particular consideration of the properties of each of the saline bodies with which water is capable of being adulterated. We shall therefore refer entirely to the article WATER in the order of the alphabet, for what can be said on this subject.

549 Water, how far an object of chemistry.

SECT. VIII. *Animal and Vegetable Substances.*

550 Chemical properties.

THE general chemical properties of these have been already taken notice of under the name of *inflammable substances*. They agree in giving out a very thick fetid oil, when distilled by a strong fire; but in other respects they differ very considerably. Most kinds of vegetables give out an acid along with the oil; but all animal substances (ants, and perhaps some other insects, excepted) yield only a volatile alkali. Some kinds of vegetables, indeed, as mustard, afford a volatile alkali on distillation, similar to that from animal substances; but instances of this kind are very rare, as well as of animals affording an acid. Both animal and vegetable substances are susceptible of a kind of fermentation, called *putrefaction*, by which a volatile alkali is produced in great plenty: there is, however, this remarkable difference between them, that many vegetable substances undergo two kinds of fermentation before they arrive at the putrefactive stage. The first is called the *vinous*, when the ardent spirits are produced, which we have already mentioned when speaking of inflammable substances. This is succeeded by the *acetous*, wherein the vegetable acid called *vinegar* is produced in plenty: and lastly, the putrefactive stage succeeds when a volatile alkali is only produced; not the smallest vestige either of ardent spirits or of vinegar remaining. On the other hand, animal substances seem susceptible only of the putrefactive fermentation; no instance having ever occurred where there was the least drop, either of ardent spirit or of vinegar, produced from a putrified animal substance. (See FERMENTATION and PUTREFACTION.)

Chemical Characters.

SECT. IX. *Of the Chemical Characters, and Tables of Elective Attraction.*

THE numerous *marks* or *characters* by which the ancient chemists used to denote many different substances were invented rather from a superstitious and fantastical principle than from any real necessity; or, perhaps, like the enigmatical language used by the alchemists, they have thereby sought to conceal their mysteries from the vulgar. In contriving these marks, they affected a great deal of ingenuity; intending them as symbols of the qualities possessed by each of the different substances. A circle being supposed the most perfect figure, was therefore used to represent the most perfect metal in nature, that is, *gold*. Silver being likewise a perfect and indestructible metal, is placed next to gold; but, on account of its inferiority, is expressed only by a crescent, as if but half gold. A circle was likewise used to denote salt of any kind, as being something elaborate and perfect. A cross was used to denote acrimony of any kind, and consequently employed for the acrimonious salts of vitriol, alkali, &c. Hence all the inferior metals have the cross some how or other combined with the marks designed to represent them. Thus, the mark for quicksilver denotes, that it hath the splendor of silver, the weight of gold, but its perfection is hindered by an acrimony represented by the cross at bottom, &c. Fire is represented by an equilateral triangle, having one of its angles uppermost. This may be considered as a rude representation of flame, which is always pointed at top. Water, again, is represented by a triangle, with an angle downwards, showing the way in which that element exerts its strength, &c. All these marks, however, as they were of no real use at first, so they are now becoming every day more and more neglected. Such of them, however, as may most readily occur in chemical books are represented and explained on Plate CXXXII. 551 Invention of marks or characters.

The French chemists have of late attempted to introduce a kind of new chemical language; and by adopting it themselves, may perhaps make it at last universal, 552 New chemical language.

Elective Attraction.

versal, as it is now impossible to understand their writings without knowing it. See the Table at the end of this article.

553 Of tables of affinities.

Tables of affinities, or *elective attractions*, are but of late invention. They are consequences of an improved state of chemistry, when the different substances were found to act upon one another in most cases according to a fixed and settled rule. The most approved table of this kind for a long time was that composed by Mr Geoffroy. It was, however, found to be very incomplete, not only as to its extent, but likewise as heat and some other circumstances were found to vary the attractions considerably, and sometimes even to reverse them. Other tables have been constructed by Mr Gellert, &c. but none hath yet appeared so complete but that many additions may be made to it. The following is that at present exhibited by Dr Black in his course of chemistry.

1. Vitriolic Acid.
Phlogiston
Terra ponderosa
Fixed alkali
Calcareous earth
Zinc
Iron
Tin
Copper
Quickfilver
Silver
Volatile alkali
Magnesia
Earth of alum.

2. Nitrous Acid.
Phlogiston
Fixed alkali
Calcareous earth
Zinc
Iron
Lead
Tin
Copper
Quickfilver
Silver
Volatile alkali.

3. Marine Acid.
Fixed alkali
Calcareous earth
Zinc
Iron
Lead
Tin
Copper
Regulus of antimony
Quickfilver
Silver
Spirit of wine
Volatile oils
Gold.

4. Sulphur.
Fixed alkali
Calcareous earth
Iron
Nickel
Copper
Lead
Tin
Silver
Regulus of antimony
Quickfilver
Arsenic.

5. Hepar Sulphuris is partially decompounded by
Quickfilver
Solution of fixed alkali
Lime-water
Volatile alkali.

6. Fixed Air.
Calcareous earth
Fixed alkali
Magnesia
Volatile alkali.

7. Alkaline Salts.
Vitriolic acid
Nitrous acid
Marine acid
Acetous acid
Volatile vitriolic acid
Sedative salt
Fixed air
Sulphur
Expressed oils.

8. Calcareous Earth.
Vitriolic acid
Nitrous acid
Marine acid
Acid of tartar
Acetous acid
Sulphureous acid and sedative salt
Sulphur.

9. Metallic Substances, Lead and Regulus of Antimony excepted.
Marine acid.
Vitriolic acid
Nirtous acid
Sulphur and acetous acid.

10. Lead.
Vitriolic acid
Marine acid
Nitrous acid
Acetous acid
Expressed oils.

11. Regulus of Antimony.
Vitriolic acid
Nitrous acid
Marine acid
Acetous acid.

12. Arsenic.
Zinc
Iron
Copper
Tin
Lead
Silver
Gold.

13. Regulus of Antimony with Metals.
Iron
Copper
Tin
Lead
Silver
Gold.

14. Quicksilver.
Gold
Lead and tin
Copper
Zinc, bismuth, and regulus of antimony.

15. Silver.
Lead
Copper
Iron.

16. Water.
Fixed alkali
Spirit of wine
Milk, alkaline salts, and some neutrals.

17. Spirit of Wine.
Water
Oils and resins.

In consequence of heat, sedative salt and the other solid acids decompound vitriolated tartar, nitre, an sea-salt.

Double Elective Attractions; which, in some cases, may be considered as exceptions to the foregoing table.

I. Those which happen in mixtures of watery substances.

1.	Acids	Volatile alkali
	Calc. earths, or metallic substances	Fixed air.
2	Vitriolic or marine acids	Mercury, silver, or lead,
	Alkalies or earths	Nitrous or acetous acids.
3	Lead	Vitriol acid
	Nitrous marine, or acetous acids	Alkalies, earths, or M. S.
4.	Silver	Marine acid
	Vitriolic, nitrous, or acetous acids	Alkaline salts, earths, or M. S.
5.	Volatile alkali	Fixed air
	Acids	Fixed alkali.
6.	Nitrous, marine, or acetous acids	Volatile alkali, magnesia, or earth of alum
	Calcareous earths	Vitriolic acid.

II. Those which happen in distillations or sublimations, and require heat.

1.	Vol. alkali	Fixed air
	Acids	Calcareous earths.
2.	Vol. alkali	Nitrous, marine, or acetous acids
	Vitriol. acid	Fixed alkali.
3.	Vol. alkali	Acetous acid
	Nitrous, marine, or vitriolic acids	Fixed alkali, or absorbent earths.

Chemical Operations.

4.	Reg. of antimon. / Sulphur	Marine acid / Quickfilver.

III. Thofe which happen in mixtures by fufion.

1.	Tin / Silver	Iron / Lead.
2.	Copper / Gold	Sulphur / Lead.
3.	M. S. / Gold	Sulphur / Reg. of ant.

The firft of thefe tables requires very little explanation. The names printed in fmall capitals, are thofe of the fubftances which have the affinity with or attract thofe below them. Thus, vitriolic acid attracts moft powerfully the phlogifton, or inflammable principle: next, fixed alkali; then, calcareous earth; and fo on, in the order in which they are marked. — The tables of double elective attractions cannot be made quite fo diftinct; though an explanation of one example will make this likewife eafy to be underftood. Thus in Table I. the firft cafe is, "If a combination of acids with calcareous earths or metallic fubftances is mixed with a combination of volatile alkali and fixed air, the acids will unite themfelves to the volatile alkali, and the fixed air to the calcareous earth or metallic fubftance.

Sect. X. *Of the different Operations in Practical Chemiftry, and the proper Inftruments for performing each.*

554 Operations in chemiftry.

The moft remarkable operations in chemiftry, and by which the greateft changes are made upon thofe bodies which are the objects of that fcience, may be comprehended under the following names. 1. Solution. 2. Filtration. 3. Precipitation, or coagulation. 4. Evaporation. 5. Cryftallization. 6. Diftillation. 7. Sublimation. 8. Deflagration. 9. Calcination. 10. Fufion. 11 Maceration, or digeftion. To which we may add, 12. Trituration, or levigation.

555 Chemifts how divided.

Before we proceed to a particular account of each of thefe operations, it is neceffary to take notice, that there are two different things propofed by thofe who enter on the practice of chemiftry. Some have nothing farther in view than the enlargement of their knowledge, or making improvements in arts which are to be practifed by others for their own advantage. Others defign to follow chemiftry as a trade, by which they hope to enrich themfelves, or to get a comfortable livelihood. But the apparatus and utenfils neceffary for performing the very fame operations are exceedingly different when experiments only are to be made, from what they muft be when thefe operations are performed with a view to profit; and fo great is this difference, than thofe who purfue chemiftry with a view to advantage, will always find themfelves very confiderable lofers if they follow the plan of an apparatus or a laboratory defigned only for making experiments. Along with the apparatus, therefore, which is commonly defcribed in chemical books, and proper only for experiments, we fhall alfo give that which is neceffary for preparing great quantities of any chemical article in the way of trade.

556 Glafs veffels, when to be ufed.

In general, thofe who practice chemiftry merely with an experimental view, ought, as much as poffible, to make ufe of glafs veffels, as not being liable to be corroded by the moft powerful folvents; and, by their tranfparency, giving an opportunity of obferving what paffes within them during the operation. But by thofe who practife chemiftry with a different view, thefe veffels ought, with equal care, to be avoided, on account of their expence and brittlenefs. This laft quality, indeed, is poffeffed by glafs in fo eminent a degree, that glafs veffels will fometimes fly to pieces, and that with confiderable violence, when ftanding by themfelves, and nothing touching them. The principle objects which a chemift ought to have in view, in performing his operations, ought to be to fave time and fuel, efpecially the former; and for this purpofe, he would find himfelf a confiderable gainer, though he fhould be at much greater expence in his apparatus than he would otherewife have occafion for.

557 Dr Black's obfervations on chemical veffels.

On the fubject of chemical veffels Dr Black obferves, that "with regard to the material of which thefe are compofed, we are very much at a lofs; and indeed there are no fuch materials in nature as are capable of anfwering the purpofes of chemifts in abfolute perfection.—The qualities are, 1. Tranfparency to allow us to fee the changes going on; 2. The power of refifting the action of acids and corrofive fubftances; 3. That they bear fudden alterations of heat and cold without breaking; 4. That they be ftrong, in order to confine elaftic vapours; and, 5. That they bear very great heat without melting. As thefe qualities, however, are not to be met with united in any one fubftance, the chemifts are obliged to have recourfe to different fubftances which poffefs fome of them differently. Thefe are, *glafs*, *metal*, and *earthen ware*.

558 Good and bad qualities of glafs as a material for chemical veffels.

Glafs is poffeffed of the two firft properties, but has the inconvenience of being apt to crack and fly in pieces, on any fudden tranfition from heat to cold, or from cold to heat. The beft method of remedying this defect, is to have the glafs made very thin, and of a round figure, that it may be all heated as equally as poffible; as it is the unequal application of the heat which caufes it break. Another requifite in the choice of chemical glaffes, is that they be well annealed. If this is not done, the glafs will either immediately fly to pieces, or be liable to break on the fmalleft accident.

559 Extreme fragility of glafs not well annealed.

That fuch glaffes fhould be liable to be broken on every flight occafion, is a phenomenon that has hitherto received no explanation. If you touch them with a diamond, with a piece of flint, glafs, &c. or expofe them to the heat of the fun, they break immediately. Dr Black has had great veffels of glafs, which broke immediately on his throwing a little fand into them to clean them. This manifeftly depends upon the fame principles as the qualities of what are called *glafs tears*.

560 Good and bad qualities of metals as materials for chemical veffels.

Glafs when well annealed is univerfally to be preferred, where great and fudden changes of heat, or much ftrength, are not required. Flint-glafs is the beft; but the coarfer kinds, as bottle-glafs, are very apt to break.

The metals have the third and fourth qualities in perfection, but are deficient in all the reft. The moft troublefome property is, that they are liable to be corroded by acids and other bodies, as is the cafe with iron and copper; though this is in fome meafure

Chemical Operations.

measure remedied by tinning; which, though it wants some of the qualities from its melting too soon, yet resists the action of many acrid substances without being so readily injured by them; but it is not entirely free from this imperfection, and is liable to be somewhat corroded and rusted. In nice operations, therefore, recourse is had to silver and even to gold vessels.

561 Of earthen ware.

Earthen ware possesses only the fifth quality in perfection, *viz.* that of bearing a violent heat without fusion. The basis of these vessels is clay, which, when good, is very convenient for the formation of vessels, and it has been used from the earliest ages of chemistry for this purpose. The requisite qualities are, 1. A considerable degree of toughness when mixed with water. 2. A great degree of hardness when burnt in the fire with a violent degree of heat. The best kind of clay thus contracts a degree of hardness scarce inferior to flint, as is the case with that of which tobacco-pipes are made; but most other kinds, such as that of which bricks are constructed, are apt to melt with a strong heat into a spongy matter. Clay, however, can seldom be used alone; for when burnt to extreme hardness, the vessels are very liable to crack. This is remedied by mixing sand reduced to a particular degree of fineness, with the clay of which the vessels are made. For this purpose both the finest and the coarsest particles of the sand must be thrown away.

562 Black lead a valuable material for some purposes.

Another substance known by the name of black lead, used in the making of pencils, resists the fire exceedingly. This, however, does not contain an ore of lead, but sulphur, and some mineral substances; when mixed with clay, however, it makes it resist the fire surprisingly. But there are some particular cases in which neither sand nor black lead can be used as a material; for the sand is easily corroded by acrid matters, and the black lead would produce other inconveniences. Clay is therefore to be taken in its unburnt state, reducing it to a powder like sand; then burning this powder with a violent heat, so as to convert it into sand. Mixing it then with raw clay, it forms a composition which answers very well for making chemical vessels, and may be employed in those particular cases where sand would not answer. Pott of Berlin has written upon the different kinds of earthen ware proper to be employed in the construction of chemical vessels. There is a French translation of it in four or five volumes.

563 Porcelain vessels when to be used.

In cases where the utmost compactness of texture is required, procelain vessels are to be chosen; which is composed of the finest clay, mixed with a stony matter, that has the quality of melting in a violent heat, and gives more compactness to the clay than it is naturally capable of receiving; but these are rather too costly for most operations. Reaumur has taught a way of converting glass into porcelain.

We shall now proceed to a particular description of each of the operations abovementioned.

564 Solution.

I. SOLUTION. By this is understood the dissolving a solid substance in a fluid, so as that the solid shall totally disappear, and become part of a transparent liquor. This operation applies particularly to salts, earths, and metals: as well as to several unctuous and inflammable substances. For performing this operation in a small way, common vials are in many cases sufficient. Where the solution is attended with effervesence and a discharge of vapours, the long-necked glasses called *matrasses*, or *bolt-heads*, (fig. 5.), are necessary. Florence flasks are indeed exceedingly well adapted for this operation, as being of the proper shape, and capable of bearing heat so well, that they may be filled with any fluid, and set on a common fire like a metalline vessel. Solution is much promoted by agitating the vessel, and by heat. In some cases, indeed, it will not take place till the mixture becomes very hot; and in such cases it will be proper to make the fluid boiling hot by itself, and then slowly to add the substance to be dissolved.

Plate CXXXIV.

When large quantities of saline matter are to be dissolved, metalline vessels must be used: but before any are made use of for this purpose, it will be necessary to make an experiment whether the salt receives any impregnation from the metal of which the vessel intended to be made use of is formed; and if this is found to be the case, it must not be used. The metals most liable to be corroded by saline bodies are iron and copper; and indeed, unless it be for the single purpose of dissolving fixed alkaline salts, iron vessels seem totally unfit for saline solutions of any kind. Copper vessels are also very liable to be corroded, and to communicate very mischevous qualities to the liquors which corrode them; for which reason, they ought never to be made use of for the purposes of solution. The metal least liable to be corroded, next to gold and silver, is lead; and therefore a chemist ought rather to provide himself with leaden vessels than those of any other metal. But though lead is not apt to be corroded by many kinds of salts, there are some which are found to act upon it, and to form therewith a very dangerous poison. The vegetable acid of vinegar is particularly apt to receive a dangerous impregnation from this metal; and therefore no solution of any salt containing this acid ought to be made in leaden vessels. It appears to be very little affected by the vitriolic or marine acids; and therefore any saline substance containing either of these acids may be safely enough dissolved in vessels made of lead.

In order to save time in making solutions, the vessels ought to be as large as possible; though even in this there must be a certain limit: for two small vessels filled with water will sooner acquire the necessary degree of heat than one large one; and in proportion as the vessel is made more capacious, the sides and bottom must be thicker, which considerably increases the expence. Fifteen or twenty English gallons is the utmost capacity of which they ever will be required; and is rather above what will on most occasions be necessary. They ought to be of a conical figure, round at the bottom; and to have a cover of thick plate-iron all around that part which is exposed to the action of the fire, that the lead may not bend on the application of heat, which it would otherwise be very apt to do. When the solution is to be made, the leaden vessel is first to be filled up with water so far as to have room for the quantity of salt intended to be dissolved: a fire is then to be applied so as to make it boil: and then the salt is to be added slowly, so as scarcely to hinder the boiling; for if a great quantity was thrown in at once, so as to cool the liquor very much, great part of the salt would concrete on the bottom, in such

CHEMISTRY.

Chemical Characters or Symbols.

Plate CXXXIII.

Acid of Fluor	Amber.	Colouring matter of	Fixed vegetable
Arsenic	Sugar of Milk.	Prussian Blue falsely	Alkali.
Borax	Vinegar.	called an Acid.	Mineral Alkali.
Sugar	Milk.	Phlogisticated vitri-	Ponderous Earth.
Tartar	Ants.	olic Acid the same w.t	Pure Air.
Sorrel	Fat.	Vol. Sulphureous Acid.	Platina.
Lemon	Phosphorus.	Dephlogisticated	Manganese.
Benzoin	Aerial.	Marine Acid.	Metallic calx.

Thackara & Vallance Sculp.t

Chemical Operations

a manner as not only to be very difficultly soluble, but even endanger the melting of the vessel. It is of some consequence also to avoid the hot steam which proceeds from the boiling water, and which issues with great force from a narrow-mouthed vessel, such as we have been describing. That the operator may be out of the reach of this, and likewise dissolve the salt in a regular and gradual manner, without any danger of its concreting on the bottom, it will be proper to have a leaden, or even a wooden, vessel, with a long handle; which is to be filled with the substance to be dissolved, then immersed in the boiling liquor, and shaken about in it, till the salt is made into a kind of thick pap, which will be in no danger of concreting. It will also be proper not to saturate the water perfectly with salt; for it will in that case be impossible to hinder part of it from settling on the bottom, where it soon acquires such a degree of heat as to melt the lead. Before any saline substance is put into water for solution, it ought to be pounded and sifted through a hair sieve.

Where large quantities of metal are to be dissolved in acids, especially the nitrous acid, glass vessels are in a manner indispensable; although the common stoneware bottles, especially those made in Holland, will answer the purpose very well, as not being liable to corrosion, and not so apt to break as the glass vessels are. They may be got of such a size as to hold three or four gallons: but no vessel in which metalline solutions are made ought ever to be above half full.

In solutions of oily and inflammable substances, cast iron vessels are perhaps the most proper of any; though copper ones are generally preferred. The copper is excessively soluble in oil, especially if it is left to cool in such a vessel; but iron is not soluble in any inflammable matter except sulphur. Copper has, however, this advantage over iron, that it is sooner cooled, as the vessels made of copper are thinner than they can be made of cast iron: so that if too great heat is applied to a copper vessel, it may be easily remedied by taking it off the fire; but in a cast iron vessel the heat continues so long as may sometimes produce dangerous consequences, even after the fire is removed.

565 Dr Black's directions for solution.

Dr Black observes, that for the purpose of solution, if no particular nor uncommon consequence follow the application of the two bodies to each other, and if none of them be very volatile, any glass or porcelain vessel that can resist the action of the substances will answer the purpose; but it often happens that they break out into violent ebullition, which produces steam; and here a common vessel is not so proper, as we would wish to have the vapour confined or condensed. We therefore choose a close vessel that will bear the heat suddenly produced by the mixture, or the heat that may be necessary to promote the action of such bodies upon one another. Of this kind is the *phiala chemica*, or matrass, in which the vapours will have time to circulate and to be condensed again, without being allowed to escape. Where the matter is in small quantity, smaller vessels somewhat of the same form are used, as Florentine flasks, which bear sudden changes of heat and cold remarkably well, on account of their thinness. In order to promote the action of bodies, it is sometimes necessary to make the fluids boil; and for this purpose we must have a matrass with a large neck, or apply another vessel to it that will receive these steams, and give them still more room for their condensation, and direct them to fall back again, when condensed, into the matrass. This is called *circulation*. Macquer describes another vessel called the *pelican*, which has been made use of for this purpose; but it is hardly ever employed, on account of its being so troublesome to procure and manage it; and the advantages arising from it may be obtained by a more simple apparatus.

566 Pelican. Fig. 6.

567 Papin's digester. Plate CXXXIII.

To this head we must refer Papin's digester, which is represented Fig. 4. It is generally made of copper, very thick and strong, open at the top, with a lid fitted to it, which applies very exactly. There are usually two projections on the side, designed to make the lid go in a particular manner, but they are unnecessary. There are other two, to which are fitted the two sides of a cross bar B B; in which cross bar there is a strong screw D, by which the lid can be pressed down very strongly. Its use is to force water to bear a stronger heat than it can do under the ordinary pressure of the atmosphere. It is sometimes furnished with an apparatus for letting out the steam, lest it should be in danger of bursting the vessel. A pipe is passed through the lid which is fitted with a valve, on which passes a lever at a very small distance from its centre of motion; and this can be made to press on the valve with different weights, according to the distance of these weights from the centre. In one constructed by Dr Black, there was another pipe below, into which a thermometer could be introduced, in order to measure the degree of heat to which the steam was raised. This machine was pretty much employed some time ago, and its effects were much admired; but we find that most things which can be dissolved in this way, can likewise be dissolved in the ordinary way by boiling water, provided it is continued for a longer time, as animal bones, from which the gelatinous parts are indeed extracted very quickly by this vessel; but the same change is produced by boiling them in water for a long time in the ordinary degree of heat.

568 Filtration.

II. Filtration. This operation is generally the attendant of solution: very few substances, of the saline kind especially, are capable of being dissolved without leaving some impurities, from which they must be freed; and the doing of this, so as to render the solution perfectly transparent, is what is understood by the word *filtration*.

For purposes merely experimental, a glass funnel and piece of paper are generally sufficient. The paper is formed into a conical cap, which being placed in the funnel with its point downwards, the funnel is then placed in the mouth of a vial; and the solution or other liquor to be filtered is poured into the paper cap, through which the liquor passes transparent, leaving its impurities on the paper. For the purpose of filtration, paper has come into such general use, that a particular kind of it is prepared under the name of *filtering paper*. This is of a reddish colour; but Dr Lewis prefers the whitish grey paper which comes from Holland about the pill boxes, as not giving any colour to the solutions which pass through it.

This operation though apparently so simple and easy, is nevertheless attended with very troublesome circumstances, on account of the great time it takes up. Even where very small quantities of liquor are to be filtered, merely

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To avoid theſe inconveniences, another method of filtration has been propoſed; namely, to uſe a number of cotton threads, the ends of which are to be immerſed in the liquor, and the other ends are to hang over the ſide of the veſſel which contains it, and to hang lower than the ſurface of the liquor. By this means they will act as ſo many capillary ſyphons, (ſee SYPHON); the liquor will ariſe in them quite pure, and be diſcharged from their lower extremities into a veſſel placed to receive it. That the liquor may flow freely into the cotton, it will be proper to wet the threads before they are uſed.

In point of efficacy, no doubt, this method excels every other; and where the operator has abundance of time and patience, may be proper for experiments; but, in the way of trade, ſuch a contrivance is evidently uſeleſs. For filtering large quantities of liquor, therefore, recourſe has been had to large funnels; earthen cullenders, or baſons full of holes in the bottom, lined with filtering paper; and to conical bags of flannel or canvas

The inconveniences attending funnels, when uſed only in the way of experiment, are much greater when they are employed for filtering large quantities of liquor; and therefore they are generally laid aſide. The earthen cullenders, too, do not anſwer any good purpoſe; nor indeed does filtration through paper in general ſucceed well. The conical flannel or canvas bags are greatly preferable: but they have this inconvenience, that the preſſure of the liquor is directed chiefly againſt one particular point, or a ſmall part of the bottom, and therefore the impurities are forcibly driven into that place; and thus the operation becomes inſufferably tedious.

The beſt method of obviating the inconveniences of filtration ſeems to be the following. Let a wooden frame of about three feet ſquare be made, having four holes, one in each corner, about three quarters of an inch in diameter. This frame is to be ſupported by four feet, the ends of which muſt project an inch or two through the holes. Thus the whole may be occaſionally ſet up and taken down ſo as to go into very little compaſs; for if the feet are properly placed, each with a little projection outwards, there will be no danger of its falling. A ſquare piece of canvas muſt alſo be procured, ſomewhat leſs than the wooden frame. On each corner of it there muſt be a very ſtrong loop, which ſlips on one of the projecting ends of the feet, ſo that the canvas may hang a little ſlack in the middle of the frame. The liquor to be filtered is now poured into the canvas, and a veſſel placed underneath to receive it. At firſt it will paſs through very foul; but being returned two or three times will become perfectly tranſparent, and will continue to run with great velocity, if the filter is kept conſtantly full. A filter of the ſize juſt now mentioned will contain ten gallons of liquid; which is a very great advantage, as the heat of ſuch a quantity of liquor is not ſoon diſſipated, and every ſolution filters much faſter when hot than when allowed to cool.

The advantages of a filter of this kind above others ariſe from the preſſure of the liquor being more equally diffuſed over a large ſpace, by which the impurities are not forced ſo ſtrongly into the cloth as to ſtop it up entirely. Yet even here, where large quantities of liquor require filtration, the cloth is apt to be ſtopped up ſo as to make the operation not a little tedious and diſagreeable. It will be proper therefore to have ſeveral cloths, that one may be applied as ſoon as another is taken off.

To promote the operation of filtration, it is very proper to let the liquors to be filtrated ſettle for ſome time; that ſo their groſſer feculencies may fall to the bottom, and thus there will be the fewer to retard the laſt part of the operation. Sometimes, however, theſe feculencies refuſe to ſettle till after a very long time; and where this happens to be the caſe, a little powdered quicklime thrown into the boiling liquor remarkably promotes the ſeparation. This, however, can only be uſed in certain caſes.

569 Schemes for filtering large quantities of water.

In ſome caſes, the diſcovery of a ready way of filtering a large quantity of liquor would be a matter of great conſequence; as where a town is ſupplied with river water, which is generally far from being clear, and often imparts a diſagreeable colour to clothes waſhed with it. Some years ago, a ſcheme was propoſed by a chemiſt for filtering muddy water in any quantity. His method was, to have a large caſk covered over in the bottom with ſtraw to the depth of ſome inches, and then filled up with ſand. This caſk was entirely open at one end, and had a hole in the other, which, by means of a leaden pipe, communicated with a large reſervoir of the water to be filtered, and which ſtood conſiderably higher than the caſk. The water which deſcended through the pipe into the caſk, having a tendency to riſe up to the ſame level with that in the reſervoir, would preſs violently againſt the ſand, and, as he thought, run over the mouth of the caſk perfectly filtrated, and free from its impurities. By this contrivance, indeed, a very violent preſſure was occaſioned, if the height of the reſervoir was conſiderable: but the conſequence was, not a filtration, but a greater degree of impurity in the water; for the ſand was forced out of the caſk along with it, and, however confined, the water always aroſe as muddy as it went in.

Where water is to be filtered in large quantity, as for the purpoſes of a family, a particular kind of ſoft ſpongy ſtones called *filtering ſtones*, are employed. Theſe, however, though the water percolates through them very fine, and in ſufficient quantity at firſt, are liable to be obſtructed in the ſame manner as paper, and are then rendered uſeleſs. A better method ſeems to be, to have a wooden veſſel, lined with lead, three or four feet wide at top, but tapering ſo as to end in a ſmall orifice at the bottom. The under part of the veſſel is to be filled with very rough ſand, or gravel, well freed from earth by waſhing. Over this, pretty fine ſand may be laid to the depth of 12 or 14 inches, but which muſt likewiſe be well freed from earthy particles. The veſſel may then be filled up to the top with water, pouring it gently at firſt, leſt the ſand ſhould be too much diſplaced. It will ſoon filter thro' the ſand, and run out at the lower orifice exceedingly tranſparent, and likewiſe in very conſiderable quantity. When the upper part of the ſand begins to be ſtopped up, ſo as not to allow

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a free paffage to the water, it may occafionally be taken off, and the earthy matter wafhed from it, when it will be equally ferviceable as before.

570 Precipitation.

III. PRECIPITATION or COAGULATION. This operation is the very reverfe of folution, and is the bringing a body fuddenly from a fluid to a folid ftate. It differs from cryftallization, in that it generally requires lefs time; and in cryftallization the fubftance affumes regular figures, whereas precipitates are always in the form of powders.

Precipitation is generally preceded by folution and filtration: it is ufed for feparating earths and metals from the acids which had kept them fufpended. When a precipitation is made of the more valuable metals, glafs veffels are to be ufed. When earths, or the imperfect metallic fubftances, are to be precipitated in large quantity, wooden ones anfwer every purpofe. If a metal is to be precipitated by an alkali, this falt muft firft be diffolved in water, then filtered, and gradually added to the metallic folution. If particular circumftances do not forbid, the falt for precipitation fhould be chofen in its cauftic ftate, or deprived of its fixed air, becaufe then a very troublefome effervefcence is avoided. To promote the operation alfo, the mixture, if contained in a glafs, is to be fhaken; or if in any other veffels, to be well ftirred after every addition of alkali. If an earth is employed to precipitate a metal, the mixture muft be in a manner conftantly ftirred or fhaken, in order to promote the precipitation; and if one metal is to be precipitated by another, that which is ufed as a precipitant muft be beaten into thin plates, that fo they may be frequently cleaned from the precipitating metal, which would otherwife very foon totally impede the operation.

Sometimes a precipitation enfues on the addition of water or fpirit of wine: but in moft cafes care muft be taken not to add too much of the fubftance which is ufed to precipitate the other; becaufe, in fuch a cafe, the precipitate may be diffolved after it has been thrown down. Thus, though volatile alkali will feparate copper from aquafortis, it will as effectually diffolve the precipitate, if too much of it is ufed, as the acid itfelf. It is proper, therefore, to proceed cautioufly, and examine a fmall quantity of the liquor from time to time. If an addition of the precipitant throws down any more, it will be proper to add fome more to the whole folution.

571 Edulcoration.

It is feldom or never that precipitation can be performed fo perfectly, but that one or other of the ingredients will prevail; and though they fhould not, a new compound, confifting of the acid united with the alkali, or other fubftance ufed for precipitation, is contained in the liquor through which the precipitate falls. It is proper, therefore, to wafh all precipitates; otherwife they can never be obtained perfectly pure, or free from a mixture of faline fubftances. This is beft done by pouring the whole into a filter, and letting the fluid part run off, as long as it will drop, without fhaking the cloth. Some water is then to be cautioufly poured all over the furface of the precipitate, fo as to difturb it as little as poffible. This water will pufh before it the faline liquor which is mixed with the powder, and render it much purer than before. A fecond or third quantity of water may be ufed, in order to wafh off all the faline matter. This is called *edulcorating* the precipitate.

572 Evaporation.

IV. EVAPORATION. This operation confifts in diffipating the moift fluid or volatile parts of any fubftance by means of heat. It moft generally fucceeds folution and filtration, being a preparatory for the operation of cryftallization.

For the evaporation of faline folutions, which have been already filtered, and which it is of confequence to preferve from even the leaft impurities, diftilling veffels are unqueftionably the moft proper; both as, by their means, the folution will be kept perfectly free from duft, and as the quantity of liquor evaporated can be known with certainty by meafuring that which comes over. This alfo is probably the moft expeditious method of evaporating, and which requires the leaft fuel. (See the detached articles EVAPORATION and DISTILLATION). With regard to veffels for evaporation, the fame thing muft be applicable which was mentioned above under *Solution*. No faline liquor muft be evaporated in a veffel which would be corroded by it; and hence iron veffels are abfolutely improper for evaporations of any kind of faline liquor whatever.— Lead is in this cafe the metal moft generally ufeful. It muft only be ufed, however, where the evaporation is not carried to drynefs; for, on account of the great fufibility of this metal, nothing could be exficcated in it without great danger of its melting. Where a faline liquor therefore is to be perfectly exficcated, the evaporation, if performed in lead veffels, muft be carried on fo far only as to form a faline pellicle on the furface of the liquor. It is then to be drawn off; for which purpofe, all evaporating veffels fhould have a cock near the bottom. The liquor muft now be put into a number of ftone-ware bafons, fet on warm fand, where the exficcation may be finifhed.

573 Cryftallization.

V. CRYSTALLIZATION. This, though commonly accounted one of the proceffes in chemiftry, is in reality only a *natural* one, and which the chemift can only prepare for, leaving the operation entirely in the hands of nature.—By cryftallization is meant the feparation of a falt from the water in which it has been diffolved, in tranfparent maffes regularly figured, and differently formed, according to the different nature of the falts.

This procefs depends upon the conftitution of the atmofphere more than any other; and therefore is difficult to be performed, nor does it always fucceed equally well; neither have there yet been laid down any rules whereby beautiful and regular cryftals can with certainty be formed at all times.

As the different falts affume very different figures when cryftallized, they are not fubject to the fame general rules in cryftallization. Nitre, Glauber's falt, vitriol of iron, and many others, cryftallize beft on having their folutions fet in a cold place after proper evaporation. Sal polychreft, and common falt, require the folution to be kept as hot as the hand can bear it during the time of cryftallizing. Soluble tartar too, and other deliquefcent falts, require to be kept warm while this operation is going on: and there are many faline fubftances, fuch as the combinations of calcareous earths and magnefia with acids, which can fcarcely be cryftallized at all.

Mr Beaumé has difcovered, that when two or more

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falts are diffolved in the fame quantity of water, when one cryftallizes, the cryftals of that falt will not contain the leaft quantity of any of the others: neither, although the liquor was acid or alkaline, will the cryftals for that reafon be either acid or alkaline, but will remain perfectly neutral; and the acid or alkaline liquor which adheres to the outfide of the cryftals may be abforbed by merely fpreading them on filtering paper.—Hence we are furnifhed with a better method of fhooting falts into large and well formed cryftals than merely by diffolving them in water; namely, by adding to the folutions, when fet to cryftallize, a certain quantity of acid or alkaline liquor, according to the nature of the falts themfelves. Thefe additions, however, are not equally proper for all falts; and it is not yet determined what kinds of falts ought to be cryftallized in alkaline, and what in acid liquors.—Soluble tartar and Seignette's falt cryftallize beft when the liquor is alkaline. Sal fedativus, fal Glauberi, and fal polychreft, require an acid if cryftallized in the cold; but fal polychreft forms into very fine and large cryftals when the folution is alkaline, and kept as hot as the hand can eafily bear.

The beft general direction that can be given with regard to the regular cryftallization of falts is, that they ought to be fet to cryftallize in as large a quantity at once as poffible; and this, as far as we have obferved, without any limit; for by this means, the cryftals are formed much larger and better figured than they poffibly can be by any other method hitherto known.—As to the form of the veffels in which falts are to be cryftallized, little can be faid with certainty. They are generally flat, and wider at top than at the bottom. The only proper material, in the large way, is lead.

574 Diftillation.

VI. Distillation. This is a kind of evaporation; only in fuch a manner, that the part of the liquor evaporated is not diffipated in the air, but preferved by making the fteam pafs through a fpiral pipe, which goes through a large veffel full of cold water, or into cold glafs receivers.

This is one of the moft common chemical operations; and as there are a variety of fubjects which require to be diftilled, there is confequently a confiderable variety both in the form of the diftilling veffels to be ufed on different occafions, and likewife in the materials of which they are made, as well as the management of the fire during the time of the operation.

Plate CXXXIV.

The moft fimple and eafily performed diftillation is that by the common copper ftill, (fig. 3). It confifts of two parts; one called the *body*, and the other the *head*. The body is a cylindrical veffel of copper, which is fometimes tinned over in the infide; but where diftillation is performed without any regard to the refiduum, the tinning is ufelefs. The upper part of the body terminates in a kind of arch, in the middle of which is a circular aperture, about one half, or fomething lefs, in diameter, of the breadth of the whole body.—Into this aperture, a round head, made likewife of copper, is fitted, fo as to be removeable at pleafure. In the top, or fometimes in the fide of the head, is inferted a pewter pipe, which communicates with a fpiral one of the fame metal, that paffes through a large wooden veffel, called the *refrigeratory*, filled with cold water; each of its ends projecting a little above and below. The ftill is to be filled two-thirds full of the fubftance to be diftilled, the head put on, and the junctures well clofed with mixture of lintfeed meal and water, or common flour or chalk and water will anfwer the fame purpofe. This mixture is called the *luting*, or *lute*. A fire being kindled under the ftill, the vapours will arife; and, being condenfed by the cold water, through which the fpiral pipe called the *worm* paffes, will run in a ftream more or lefs ftrong as the fire is more or lefs haftily urged, and is catched in a receiver fet underneath.

This kind of diftilling veffels is proper for procuring the effential oils of vegetables, vinous fpirits from fermented liquor, and for the rectification of thefe after they are once diftilled. Even the acetous acid may be very conveniently diftilled in a copper veffel, provided the worm and all the defcending parts of the pipe which communicates with it be of pewter, otherwife a mifchievous impregnation of copper would be communicated to the diftilled vinegar. The reafon of this is, that copper is not diffolved by vinegar, or in very fmall quantity, when that acid is boiled in it; but if the metal is expofed to the action of the acid, when cold, or to its vapours, a confiderable diffolulution takes place. For this reafon, too, the ftill muft be wafhed out after the operation while it continues hot, and muft be very carefully freed from the leaft remains of acid, otherwife it will be much corroded.

Copper-ftills ought to be of as large a fize as poffible: but Dr Lewis very juftly obferves, that, in common ones, the width of the worm is by no means proportionable to the capacity of the ftill: hence the vapour which iffues from a large furface being violently forced through a fmall tube, meets with fo much refiftance as fometimes to blow off the ftill-head. This inconvenience is ridiculoufly endeavoured to be prevented by ftrongly tying or otherwife forcing down the head; by which means, if the worm fhould happen to be choaked up, a terrible explofion would enfue: for no ligatures, or any other obftacle whatever, have yet been found ftrong enough to refift the elaftic force of fteam, and the greater obftacle it has to overcome, the greater would the explofion be.—Dangers of this kind might be totally avoided by having the worm of a proper degree of widenefs. 575

Mineral acids how diftilled.

Sometimes, however, matters are to be diftilled, fuch as mineral acid fpirits, which would corrode any kind of metalline veffels; and for thefe only earths, or the clofeft kind of ftone-ware, can be ufed. Thefe are more eafily condenfed than the fteams of aqueous or vinous liquors, and therefore do not require to be paffed through a pipe of fuch a length as is ufed for condenfing the fteams from the common ftill. In thefe cafes, where a violent heat is not neceffary, and the 576 diftillation is to be performed in glafs veffels, the retort is ufed (fig. 4.) When a fluid is to be put into this veffel, the retort muft be laid upon its back on fand, or any other foft matter that will fupport it without breaking. A funnel muft alfo be procured with a long ftem, and a little crooked at the extremity, that the liquor may pafs at once into the belly of the retort, without touching any part of its neck; otherwife the quantity which adhered to the neck would pafs into the receiver when the retort was placed in a proper fituation for diftilling, and foul the produce. When the veffel is properly filled, which ought never to be above two-thirds, it is to be fet in a fand-bath: that is, in an iron pot, of a proper thicknefs,

Retort.

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577 Luting for acid fpirits. The luting for acid fpirits ought to be very different from that ufed in other diftillations; for thefe will penetrate the common lutes fo as to make them liquid and fall down into the receiver. Some have ufed retorts the necks of which were ground to the receivers with emery; but thefe are very difficult to be procured, and are expenfive, and confequently have never come into a general ufe. Various kinds of lutes have been propofed, but the preference feems due to a mixture of clay and fand. We are not to underftand, however, that every kind of clay is fit for this purpofe: it muft only be fuch as is not at all, or very little, affected by acids; and this quality is only poffeffed by that kind of which tobacco-pipes is made. Trial ought to be made of this before the diftillation is begun, by pouring a little nitrous acid on the clay intended to be made ufe of. If a violent effervefcence is raifed, we may be fure that the clay is unfit for the purpofe. Finely powdered alabafter would anfwer extremely well, had it the ductility of clay. As this kind of lute remains foft for a confiderable time, it ought to be farther fecured by a bit of rag fpread with fome ftrong cement, fuch as quicklime mixed with the white of an egg, *&c.* Matters, however, ought to be managed in fuch a manner, that the luting may give way, rather than the veffel burft; which would not only occafion a certain lofs of the materials, but might endanger the perfons who are ftanding by.

578 *Balneum arenæ.* The iron pots commonly ufed for diftillations by the fand-bath, or *balneum arenæ*, are commonly made very thick; and are to be fold at large founderies, under the name of *fand-pots*. The fhape of thefe, however, is by no means eligible: for, as they are of a figure nearly cylindrical, if the retort is of fuch a fize as almoft to fill their cavity, it cannot be put into them when full, and often pretty heavy, without great danger of touching the fides of the pot; and in this cafe, touching and *breaking* are fynonymous expreffions. It is much better, therefore, to have them in the figure of a punch-bowl; and the common caft-iron kettles, which may be had much cheaper than the fand-pots ufually fold, anfwer extremely well. If the diftilling veffel is placed in a pot filled with water, the diftillation is faid to be performed in a water-bath, or *balneum mariæ*.

When the matter to be condenfed is very volatile, a number of open receivers with two necks, called *adopters* (fig. 7.) may be ufed, with a clofe receiver at the end. Each of thefe adopters muft be luted with as much care as when only a fingle receiver is made ufe of. Veffels of a fimilar kind were formerly much ufed by chemifts for particular fublimations, under the name of *aludels*. 579 Adopters of aludels.

Formerly, inftead of retorts, a veffel called a *cucurbit*, (fig. 5, and 6.) with a head like the common ftill, called an *alembic*, were ufed; but the more fimple figure of the retort gives it greatly the preference. It is but feldom that veffels of this kind are ufeful, which will be taken notice of when defcribing the particular operations; and if at any time an alembic head fhould be neceffary, its ufe may be fuperfeded by a crooked glafs tube, which will anfwer the purpofe equally well.

Sometimes a very violent fire is required in diftillations by the retrot. Here, where it is poffible, glafs or earthen veffels fhould be avoided, and iron pots fubftituted in their ftead. The hardeft and beft caft iron, however, will at laft melt by a vehement heat; and therefore there is a neceffity for ufing earthen ware, or coated glafs. This laft is better than moft kinds of earthen ware, as being lefs porous; for when the veffel is urged by a very intenfe heat, the glafs melts, and forms a kind of femivitreous compound with the infide of the coating, fo that its figure is ftill preferved, and the accidental cracks in the luting are filled up. 580

Coating of glaffes. For coating of veffels, mixtures of colcothar of vitriol, fand, iron filings, blood, chopped hair, *&c.* have been recommended. We cannot help thinking, however, that the fimple mixture of tobacco-pipe clay and fand is preferable to any other; efpecially if, as Dr Black directs, that part next the glafs is mixed with charcoal duft.

The proportions recommended by the Doctor for luting the joints of veffels, are four parts of fand and one of clay; but for lining the infides of furnaces, and we fhould think, likewife for coating glafs veffels, he directs 6 or 7 of fand to 1 of clay, that the contraction of the clay in drying may thereby be the more effectually prevented. Befides this, he directs a mixture of three parts of charcoal-duft with one of clay to be put next the furnace itfelf, as being more apt to confine the heat; but poffibly the firft compofition might be fufficient for glaffes.

The coating of large glaffes muft be a very troublefome and tedious operation; and therefore coated glafs is never ufed but in experiments. When large diftillations are to be performed in the way of trade, recourfe muft be had either to iron pots, or to earthen ware. Of the moft proper kinds of earthen ware for refifting violents heat, we fhall take notice under the article *Fufion*.

In all diftillations by the retort, a confiderable quantity of air, or other incondenfible vapour, is extricated; and to this it is abfolutely neceffary to give vent, or the veffel would be burft, or the receiver thrown off. For this purpofe, Dr Lewis recommends an open pipe to be inferted at the luting, of fuch an height as will not allow any of the vapour to efcape; but this we cannot approve of, as by that means a conftant communication is formed between the external atmofphere and the matters contained in the retort and receiver, which is at all times to be avoided as much as poffible, and in fome cafes, as the diftillation of phofphorus, would be very dangerous. The having a fmall

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fmall hole drilled in the receiver, which is to be now and then opened, muft anfwer the purpofe much better, although it takes more attendance; but if the operator is obliged to leave the veffels for fome time, it will be convenient either to leave the little hole open, or to contrive it fo that the wooden peg may be pufhed out with lefs force than is fufficient to break the lute.

581 Sublimation.

VII. SUBLIMATION. This, properly fpeaking, is only the diftillation of a dry fubftance; and therefore, when volatile matters, fuch as falt of hartfhorn, are to be fublimed, the operation is performed in a glafs retort fet in a fand-bath; and the falt paffes over into the receiver. The cucurbit and alembic were formerly much in ufe for this purpofe; and a blind head, without any fpout, was applied. A much fimpler apparatus, however, is now made ufe of. A globe made of very thin glafs, or an oblong veffel of the fame kind, anfwers the more common purpofes of fublimation. For experiments, Florence flafks are excellent: as being both very cheap, and having the neceffary fhape and thinnefs requifite for bearing the heat without cracking. The matter to be fublimed muft not, on almoft any occafion, take up more than a third part of the fubliming veffel. It is to be fet in a fand-bath, that the heat may be more equally applied than it could otherwife be. The heat muft be no greater, or very little, than is neceffary for fublimation, or it will be in danger of flying out at the mouth of the fubliming veffel, or of choaking it up fo as to burft. The upper part of the veffel, too, muft by no means be kept cool, but flightly covered with fand, that the matter may fettle in a kind of half melted ftate, and thus form a compact hard cake, which is the appearance fublimates are expected to have. Hence this operation requires a good deal of caution, and is not very eafily performed.

582 Deflagration.

VIII. DEFLAGRATION. This operation is always performed by means of nitre, except in making the flowers of zinc. It requires open veffels of earth or iron; the latter are very apt to be corroded, and the former to imbibe part of the matter. To perform this procefs with fafety, and without lofs, the nitre ought to be mixed with whatever matter is to be deflagrated with it, and thrown, by little and little into the veffel previoufly made red-hot. If much is put in at once, a great deal will be thrown out by the violent commotion; and to perform this operation in clofe veffels is in a manner impoffible, from the prodigious quantity of elaftic vapour generated by the nitre. Care muft alfo be taken to remove the whole mixture to fome diftance from the fire, and not to bring back any fpark from the quantity deflagrating, with the fpoon which puts it in; otherwife the whole would irremediably be confumed at once.

583 Calcination.

IX. CALCINATION. This is the fubjecting any matter to a heat fo violent as to diffipate fome part of it, without melting what remains. It is often practifed on metallic fubftances, particularly lead, for obtaining the calx of that metal called *minium*, or red lead.

This operation, as indeed all other chemical ones, is beft performed in large quantities, where a particular furnace is conftructed on purpofe, and a fire kept on day and night without interruption. The flame is made to play over the furface of the metal, and it is continually ftirred fo as to expofe different parcels of it to the action of the heat.

584 Fufion.

X. FUSION. This is when a folid body is expofed to fuch a degree of heat as makes it pafs from a folid to a fluid ftate; and as different fubftances are poffeffed of very different degrees of fufibility, the degrees of melting heat are very various.

Befides the true fufion, there are fome kinds of falts which retain fo large a proportion of water in their cryftals, as to become entirely fluid upon being expofed to a very fmall degree of heat. This is commonly called the *watery fufion*; but is really a *folution* of the falt in that quantity of water retained by it in its cryftalline form: for fuch falts afterwards become folid by the evaporation of the water they contained: and then require a ftrong red heat to melt them thoroughly, or perhaps are abfolutely infufible.

Of all known fubftances, unctuous and inflammable ones become fluid with the leaft heat: then come the more fufible metals, lead, tin, and antimony; then fome of the more fufible falts; and then the harder metals, filver, gold, copper, and iron; then the mixtures for making glafs; and laft of all, the metal called *platina*, which has hitherto been incapable of fufion, except by the violent action of the fun-beams in the focus of a large burning glafs. This fubftance feems to be the moft refractory of all others, even the hardeft flints melting into glafs long before it. (See PLATINA.)

Fufion of fmall quantities of matter is ufually performed in pots called *crucibles*; which, as they are required to ftand a very violent heat, muft be made of the moft refractory materials poffible.

585 Crucibles, proper materials for.

The making of crucibles belongs properly to the potter: but as a *chemift* ought to be the judge of their compofition, we fhall here give fome account of the different attempts to make thefe veffels of the neceffary ftrength.

All earthen veffels are compofed, at leaft partly, of that kind which is called the *argillaceous earth* or *clay*, becaufe thefe only have the neceffary ductility, and can be formed into veffels of the proper form. Pure clay is, by itfelf, abfolutely unfufible; but is exceedingly apt to crack when expofed to fudden changes of heat and cold. It is alfo very apt to melt when mixed with other fubftances, fuch as calcareous earths, &c. When mixed in a certain proportion with other materials, they are changed with violent heat into a kind of half-melted fubftance, fuch as our ftone-bottles. They cannot be melted completely, however, by almoft any fire; they are alfo very compact, and will contain the moft fufible fubftances, even glafs of lead itfelf; but as they are very apt to crack from fudden changes of heat and cold, they are not fo much ufed; yet, on particular occafions, they are the only ones which can be made ufe of.

The more denfe any kind of veffels are, the more apt they are, in general, to break by a fudden application of heat or cold: hence crucibles are not, in general, made of the greateft denfity poffible: which is not at all times required. Thofe made at Heffe, in Germany, have had the beft reputation for a long time. Mr Pott, member of the Academy of Sciences at Berlin, hath determined the compofition of thefe crucibles to be, one part of good refractory clay, mixed with two parts of fand, of a middling finenefs, from which the fineft part has been fifted. By fifting the finer particles from the fand, too great compactnefs is avoided: but

Chemical Operations. but at the same time this mixture renders them apt to be corroded by vitrifying matters kept a long time in fusion; for these do not fail to act upon the sand contained in the composition of the crucible, and, forming a vitreous mass, at last run through it.

This inconvenience is prevented, by mixing, instead of sand, a good baked clay in gross powder. Of a composition of this kind are made the glass-house pots, which sometimes sustain the violent heat employed in making glass for several months. They are, however, gradually consumed by the glass, and become constantly more and more thin.

586 Platina, a desirable material. As the containing vessel, however, must always be exposed to a more violent heat than what is contained in it, crucibles ought to be formed of such materials as are not vitrifiable by the heat of any furnace whatever. But from the attempts made to melt platina, it appears, that of all known substances it would be the most desirable for a melting vessel. Hessian crucibles, glass-house pots, Sturbridge clay, in short every substance which could be thought of to resist the most violent heat, were melted in such a manner as even to stop up the pipes of large bellows, while platina was not altered in the least; and Messrs Macquer and Beaume have shown, that though platina cannot be melted so as to cast vessels of it, it may nevertheless be cupelled with lead so as to become malleable, and thus vessels might otherwise be made from that substance. The extreme scarcity of this mineral, however, leaves as yet little room to hope for any thing from it, though Mr Achard has found a method of forming crucibles from this refractory substance. It consists in moulding the precipitate made with sal ammoniac into the form of a crucible, and then applying a sudden and very violent heat, which fuses this calx.

587 Achard's method of making crucibles of platina.

Mr Pott has made so many experiments upon clays mixed with different substances, that he has in a manner exhausted the subject. The basis of all his compositions was clay. This he mixed in different proportions with metallic calces, calcined bones, calcareous earths, talcs, amianthus, asbestus, pumice-stones, tripoli, and many others; but he did not obtain a perfect composition from any of them. The best crucibles, according to Scheffer, cannot easily contain metals dissolved by sulphur, in the operation of parting by means of sulphur. They may be made much more durable and solid, by steeping them a few days in linseed-oil, and strewing powdered borax upon them before they are dried.

588 Mr Pott's directions. The result of Mr Pott's experiments are: 1. Crucibles made of fat clays are more apt to crack when exposed to sudden heat, than those which are made of lean or meagre clays. *Meagre clays* are those which contain a considerable quantity of sand along with the pure argillaceous earth: and *fat clays* are those which contain but little. 2. Some crucibles become porous by long exposure to the fire, and imbibe part of the contained metals. This may be prevented, by glazing the internal and external surfaces; which is done by moistening these with oil of tartar, or by strewing upon them, when wetted with water, powdered glass of borax. These glazings are not capable of containing glass of lead. 3. Crucibles made of burnt clay grossly powdered, together with unburnt clay, were much less liable to crack by heat than crucibles made of the same materials where the burnt clay was finely powdered, or than crucibles made entirely of unburnt clay.

4. If the quantity of unburnt clay be too great, the crucible will be apt to crack in the fire. Crucibles made of 10 ounces of unburnt clay, 10 ounces of grossly powdered burnt clay, and three drachms of calcined vitriol, are capable of retaining melted metals, but are pervaded by glass of lead. The following composition is better than the preceding: Seven ounces of unburnt clay, 14 ounces of grossly powdered burnt clay, and one drachm of calx of vitriol. These crucibles may be rendered more capable of containing glass of lead, by lining their internal surfaces, before they are baked, with unburnt clay diluted with water. They may be further strengthened by making them thicker than is usually done; or by covering their external surfaces with some unburnt clay, which is called *arming* them. 5. The composition of crucibles most capable of containing the glass of lead, was 18 parts of grossly powdered burnt clay, as much unburnt clay, and one part of fusible spar. These crucibles must not, however, be exposed too suddenly to a violent heat. 6. Crucibles capable of containing glass of lead very well, were made of 24 parts of unburnt clay, four parts of burnt clay, and one part of chalk. These require to be armed. 7. Plume alum powdered, and mixed with whites of eggs and water, being applied to the internal surface of a Hessian crucible, enabled it to retain for a long time glass of lead in fusion. 8. One part of clay, and two parts of Spanish chalk, made very good crucibles. The substance called *Spanish chalk* is not a calcareous earth, but appears to be a kind of steatites. 9. Two parts of Spanish chalk, and one part of powdered tobacco-pipes, made good lining for common crucibles. 10. Eight parts of Spanish chalk, as much burnt clay, and one part of litharge, made solid crucibles. 11. Crucibles made of black lead are fitter than Hessian crucibles for melting metals; but they are so porous, that fused salts pass entirely thro' them. They are more tenacious than Hessian crucibles, are not so apt to burst in pieces, and are more durable. 12. Crucibles placed with their bottoms upwards, are less apt to be cracked during the baking, than when placed differently. 13. The paste of which crucibles are made, ought not to be too moist; else, when dried and baked, they will not be sufficiently compact: hence they ought not to be so moist as to be capable of being turned on a potter's lathe; but they must be formed in brass or wooden moulds.

589 Materials most capable of resisting glass of lead.

On this subject Dr Lewis hath also made several observations; the principal of which are, 1. Pure clay softened to a due consistence for being worked, not only coheres together, but sticks to the hands. In drying, it contracts 1 inch or more in 12; and hence it is very apt to crack, unless it is dried exceeding slowly. In burning, it is subject to the same inconvenience, unless very slowly and gradually heated. When thoroughly burnt, if it has escaped those imperfections, it proves solid and compact; and so hard as to strike fire with steel. Vessels made of it are not penetrated by any kind of liquid; and resist salts and glasses brought into the thinnest fusion, excepting those which by degrees corrode and dissolve the earth itself, as glass of lead; and even this penetrating glass is resisted by it better than by almost any other earth; but, in counterbalance to these good qualities, they cannot be heated or cooled, but with such precautions as can

590 Dr Lewis's observations.

rarely be complied with in the way of business, without cracking, or flying in pieces.

2. Clay that has been once exposed to any considerable degrees of heat, and then powdered, has no longer any tenacity. Fresh clay, divided by a due proportion of this powder, proves less tenacious than by itself; not sticking to the hands, though cohering sufficiently together. It shrinks less in drying, is less apt to crack, and less susceptible of injury from alterations of heat and cold; but at the same time is less solid and compact. Considerable differences are observed in these respects; not only according to the quantity of dividing matter, but according as it is in finer or coarser powder.

3. Vessels made with a moderate proportion of fine powder, as half the weight of the clay, are compact and solid, but still very apt to crack, from sudden heat or cold: those with a larger proportion, as twice or thrice the quantity of the clay, are free from that imperfection, but so friable as to crumble between the fingers. Nor does there appear to be any medium between a disposition to crack and to crumble; all the compounds made of clay and fine powders having the one or the other, or both imperfections. Coarser powders of the size of middling sand, form, with an equal weight of clay, compounds sufficiently solid, and much less apt to crack than the mixtures with fine powders. Two parts of coarse powder, and one of clay, prove moderately solid, and but little disposed to crack: a mixture of three parts and one, tho' heated and cooled suddenly, does not crack at all, but suffers very fluid substances to transude through it; solidity, and resistance to quick vicissitudes of heat and cold, seeming here also to be incompatible.

4. Pure clay, mixed with pure clay that has been burnt, is no other than one simple earth; and is neither to be melted nor softened, nor made in any degree transparent with the most intense fires.

5. Mixtures of clay with gypseous earths burn whiter than clay alone; in certain proportions, as two parts of clay to three of gypsum, they become, in a moderate fire, semi-transparent, and in a strong one they melt.

6. Calcareous earths in small proportion bake tolerably compact and white; and added to other compositions, seem to improve their compactness. If the quantity of the calcareous earth nearly equals that of the clay, the mixture melts into a yellow glass; if it considerably exceeds, the product acquires the qualities of quicklime.

7. Vessels made from clay and sand, in whatever proportion, do not melt in the strongest fire; but they sometimes bend or soften, so as to yield to the tongs. Glasses in thin fusion penetrate them by dissolving the sand. If gypseous or calcareous earths e urged in such crucibles with a vehement heat, the vessels and their contents run all into one mass. In moderate fires, these vessels prove tolerably compact, and retain most kinds of salts in fusion: but they are liable to crack, especially when large; and do not long sustain melted metals, being burst by their weight. Such are the Hessian crucibles.

8. Mixtures of clay and black-lead, which seems a species of talc, are not liable to crack from alternations of heat and cold; but are extremely porous. Hence black-lead crucibles answer excellently for the melting of metals, and stand repeated fusions; whilst salts flowing thin, transude through them almost as water through a sieve: sulphureous bodies, as antimony, corrode them.

9. Pure clay, softened with water, and incrustated on earthen vessels, that have been burnt, does, not adhere to them, or scales off again upon exposure to the fire; applied to unburnt vessels, it adheres and incorporates. Divided clay unites with them in both states. Vitreous matters, melted in vessels of pure clay, adhere so firmly as not to be separated; from vessels of divided clay they may be knocked off by a hammer.

10. The saline fluxes which promote the fusion of clay, besides the common ones of all earths, alkali and borax, are chiefly arsenic fixed by nitre, and the fusible salt of urine; both which have little effect on the other earths though mixed in a lager proportion. Nitre, which readily brings the crystalline earths into fusion, and sal mirabile and sandiver, powerful fluxes for the calcareous earths, do not perfectly vitrify with clay. Burnt clay does not differ in these respects from such as has not been burnt; nor in that singular property of vitrifying with gypseous or calcareous earths, without any saline or metallic addition; the utmost vehemence of fire seeming to destroy only its ductility, or that power by which it coheres when its parts are moistened with water.

But though it seems impossible to make perfect vessels from mixtures of clay in its two different states, of burnt and unburnt, more is to be hoped from the mixtures which are employed in making porcelain. Manufactories of this kind of ware have been attempted in different countries, (see PORCELAIN); and in some places the qualities requisite for chemical vessels have been given to it in a very surprising degree. The count de Lauraguais, a French nobleman, and member of the academy of sciences, has distinguished himself in a very eminent manner by attempts of this kind. The translator of the chemical dictionary assures us, that he had it from a gentleman of undoubted veracity, that this nobleman having heated a piece of his porcelain red hot, threw it into cold water, without breaking or cracking it.

591 More perfect vessels to be hoped for from porcelain.

The most useful attempt, however, for the purposes of chemistry, seems to be the discovery by Mr Reaumur of converting common green glass into porcelain. This was published as long ago as the year 1739; yet we have scarce heard of any chemist, no not Dr Lewis himself, who has made trial of chemical vessels formed of this sort of porcelain, although the very use to which Mr Reaumur thought the preparation could be applicable was that of bringing chemical vessels to a degree of perfection which could not otherwise be done. The following is the result of Mr Reaumur's experiments.

592 Mr Reaumur's porcelain.

Green glass, surrounded with white earthy matters, as white sand, gypsum, or plaster of Paris, &c. and exposed to a considerable heat not strong enough to alter its figure, as that of a potter's furnace, acquires different shades of blue, and by degrees begins to grow white. On breaking the glass, the white coat appears to be composed of fine, white, glossy, satin-like fibres, running transversely, and parallel to one another; the glass in the middle being scarcely altered. On continuing the cementation, the change proceeds further and further, till at length the white fibrous

parts

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parts from both ſides meet in the middle, and no appearance of glaſs remains. By this means, entire veſſels of glaſs may be changed into procelain.

The ſubſtance into which glaſs is thus converted, is opaque, compact, internally of great whiteneſs, equal to that of the fineſt china-ware; but, externally, of a much duller hue. It is conſiderably harder than glaſs, much leſs fuſible in the fire, and ſuſtains alterations of heat and cold without injury. Veſſels of it, cold, bear boiling liquors; and may be placed on the fire at once, without danger of their cracking. "I have put a veſſel of this porcelain (ſays the author) into a forge, ſurrounded it with coals, and kept vehemently blowing for near a quarter of an hour; I have melted glaſs in this veſſel, without its having ſuffered any injury in its figure." If means could be found of giving the outſide a whiteneſs, equal to the internal part, glaſs veſſels might thus be converted into a valuable kind of porcelain ſuperior to all that have hitherto been made. Chemiſtry, ſays he, may receive from this diſcovery, in its preſent ſtate, ſuch veſſels as have been long wanted; veſſels which, with the compactneſs and impenetrability of glaſs, are alſo free from its inconveniences.

The common green glaſs bottles yield a procelain of tolerable beauty; window-glaſſes, and drinking-glaſſes, a much inferior one; while the finer kinds of cryſtalline glaſſes afforded none at all. With regard to the cementing materials, he found white ſand and gypſum, or rather a mixture of both, to anſwer beſt. Coloured earths generally make the external ſurface of a deeper or lighter brown colour; ſoot and charcoal, of a deep black, the internal part being always white.

593 Dr Lewis's experiments.

The account of this kind of porcelain given by Mr Reaumur, induced Dr Lewis, who had alſo obſerved the ſame changes on the bottom of glaſs-retorts expoſed to violent heat in a ſand-bath, to make further experiments on this matter; an account of which he has publiſhed in his *Philoſophical Commerce of Arts*. The reſults of his experiments were, 1. Green glaſs, cemented with white ſand, received no change in a heat below ignition. 2. In a low red heat, the change proceeded exceeding ſlowly; and in a ſtrong red heat, approaching to white, the thickeſt pieces of glaſs bottles were thoroughly converted in the ſpace of three hours. 3. By continued heat, the glaſs ſuffered the following progreſſive changes: firſt, its ſurface became blue, its tranſparency was diminiſhed, and a yellowiſh hue was obſervable when it was held between the eye and the light. Afterwards it was changed a little way on both ſides into a white ſubſtance, externally ſtill bluiſh; and, as this change advanced ſtill further and further within the glaſs, the colour of the vitreous part in the middle approached nearer to yellow: the white coat was of a fine fibrous texture, and the fibres were diſpoſed nearly parallel to one another, and tranſverſe to the thickneſs of the piece: by degrees the glaſs became white and fibrous throughout, the external bluiſhneſs at the ſame time going off, and being ſucceeded by a dull whitiſh or dun colour. By a ſtill longer continuance in the fire, the fibres were changed gradually from the external to the internal part, and converted into grains; and the texture was then not unlike that of common porcelain. The grains, at firſt fine and ſomewhat gloſſy, became by degrees, larger and duller; and at laſt the ſubſtance of the glaſs became porous and friable, like a maſs of white ſand ſlightly cohering. 4. Concerning the qualities of this kind of porcelain, Dr Lewis obſerves, that, while it remained in the fibrous ſtate, it was harder than common glaſs, and more able to reſiſt the changes of heat and cold than glaſs, or even porcelain; but, in a moderate white heat, was fuſible into a ſubſtance not fibrous, but vitreous and ſmooth, like white enamel; that when its texture had become coarſely granulated, it was now much ſofter and unfuſible: and laſtly, that when ſome coarſely granulated unfuſible pieces, which, with the continuance of a moderate heat, would have become porous and friable, were ſuddenly expoſed to an intenſe fire, they were rendered remarkably more compact than before; the ſolidity of ſome of them being ſuperior to that of any other ware.

594 This ſubject ſtill imperfect.

It ſeems ſurpriſing that this able chemiſt, who on other occaſions had the improvements of the arts ſo much at heart, did not put ſome veſſels of this kind of porcelain to other ſevere trials, beſides attempting to fuſe it by itſelf with a violent fire: for though pieces of it were abſolutely unfuſible, we are not ſure but they might have been corroded by alkaline ſalts, acids, calcareous earths, or glaſs of lead; nay, it ſhould ſeem very probable that they would have been ſo: in which caſe they would not be much ſuperior to the veſſels made from earthy materials. When a firſt-rate chemiſt publiſhes any thing in an imperfect ſtate, inferior ones are diſcouraged from attempting to finiſh what he has begun; and thus, notwithſtanding that theſe experiments have been ſo long publiſhed, nobody has yet attempted to inveſtigate the properties of this kind of porcelain, by getting chemical veſſels made of it, and trying how they anſwer for crucibles, or retorts.

All that has been ſaid concerning the proper materials for crucibles, muſt likewiſe be applicable to the materials for retorts, which are required to ſtand a very violent heat. Mr Reaumur's porcelain bids faireſt for anſwering the purpoſe of retorts as well as crucibles. The great diſadvantage of the common, earthen ones, is, that they ſuffer a quantity of volatile and penetrating vapours to paſs through them. This is very obſervable in the diſtillation of phoſphorus; and though this ſubſtance has not hitherto been uſed for any purpoſe in medicine, and very little in the arts, its acid only being ſometimes uſed as a flux, if veſſels could be made capable of confining all the ſteams and at the ſame time bearing the heat neceſſary for its diſtillation, phoſphorus, perhaps, might be obtained in ſuch quantity, as to ſhow that it is a preparation not altogether uſeleſs.

595 [596] Stone-ware veſſels corroded.

With regard to ſtone-ware veſſels, and all thoſe into which the compoſition of ſand or flint enters, we ſhall only further obſerve, that they will be corroded by fixed alkaline ſalts, eſpecially of the cauſtic kind, in a very moderate heat. Dr Black, having evaporated ſome cauſtic ley in a ſtone-ware baſon, and then melted the dry ſalt in the ſame veſſel, found it ſo corroded, as afterwards to be full of ſmall holes; and he found nothing to reſiſt the action of this ſalt ſo well as ſilver.

597 Wedgewood's ware.

On the ſubject of chemical veſſels, we have now, however, to add the improved earthen ware of Mr Wedgewood; in which the properties of compactneſs, infuſibility and the power of reſiſting ſudden changes of heat and cold, are ſaid to be united, ſo that it promiſes to be a very valuable addition to the chemical apparatus.

598 Maceration. 11. Maceration, or Digestion. This is the mixing two bodies, generally a solid and a fluid, together, and then exposing them to a moderate degree of heat for a considerable length of time, that so they may have the better opportunity of acting upon one another. Digestion is usually performed in the glasses already mentioned, called *matrasses* or *bolt-heads*; and is done in a sand-heat. When any of the substances are very volatile, as spirit of wine; or when the matter requires to be heated so considerably that a quantity of vapour will be raised, the necks of the bolt-heads ought to be pretty long; or a tin pipe may be inserted, of sufficient length to prevent the escape of any part of the steam.

599 Levigation. 12. Levigation. This is the reducing any body to a very fine powder, which shall feel quite soft between the fingers or when put into the mouth. It is performed by grinding the substance upon a flat marble stone, with some water, or by rubbing it in a marble mortar. In the large way, levigation is performed by mills drawn by horses, or driven by water; some of them are so small as to be turned by the hand. They consist of two smooth stones, generally of black marble, or some other stone equally hard, having several grooves in each, but made to run in contrary directions to one another when the mill is set in motion. The matter being mixed with water, is put in by a funnel, which is fixed into a hole in the upper stone, and turns along with it. The under millstone has round it a wooden ledge, whereby the levigating matter is confined for some time, and at length discharged, by an opening made for that purpose, when it has accumulated in a certain quantity.

In this operation, when the matters to be levigated are very hard, they wear off a part of the mortar, or stones on which they are levigated; so that a substance perfectly hard, and which could not be worn by any attrition, is as great a desideratum for the purposes of levigation, as one which could not be melted is for those of fusion. Dr Lewis proposes the porcelain of Mr Reaumur as an improvement for levigating planes, mortars, *&c.* because, while in its fibrous state, it is considerably harder than glass, and consequently much less liable to abrasion by the harder powders.

In many cases levigation is very much accelerated by what is called *elutriation*. This is the method by which many of the painters colours are prepared of the requisite fineness; and is performed by mixing any substance not totally reduced to the necessary degree of fineness, with a sufficient quantity of water, and stirring them well together. The finer parts of the powder remain some time suspended in the water, while the grosser particles fall to the bottom. The separation is then easily made, by pouring off the water impregnated with these fine parts, and committing the rest to the levigating mill, when it may again be washed; and this may be repeated till all the powder is reduced to the utmost fineness. Substances soluble in water cannot be levigated in this manner.

Of Chemical Furnaces.

The two general divisions we have already mentioned of those who practice chemistry, namely, those who have no other view than mere experiment, and those who wish to profit by it, render very different kinds of furnaces necessary. For the first, those furnaces are necessary which are capable of acting upon a small quantity of matter, yet sufficient for all the changes which fire can produce from simple digestion to the most perfect vitrification. For the others, those are to be chosen which can produce the same changes upon very large quantities of matter, that as much may be done at once as possible.

600 Portable furnace. To avoid the trouble and expence of a number of furnaces, a portable one hath long been a desideratum among those chemists who are fond of making experiments. One of the best of those, if not the very best, that hath yet appeared, is that described in Shaw's edition of Boerhaave's chemistry, and represented fig. 1. Plate CXXXIV.

This furnace is made of earth; and, as the workmanship of a furnace requires none of the neatness or elegance which is required in making potters vessels, any person may easily make a furnace of this kind for himself, who has time and patience for so doing. With regard to the most proper materials, all that we have said concerning crucibles and retorts must be applicable to the materials for constructing a furnace; only here we need not care so much for the porosity, or disposition to crumble, as when crucibles or other distilling vessels are to be made.

Plate iron is commonly directed for the outside of portable furnaces; but we cannot help thinking this is a very needless expence, seeing the coating which it necessarily requires on the inside may be supposed to harden to such a degree as soon to support itself, without any assistance from the plate-iron. This will be the less necessary, if we consider, that, for the thickness of the walls of any furnace where a considerable heat is wanted, two or three inches are by no means sufficient. When the inside of a furnace is heated, the walls, if very thin, are soon penetrated by the heat, and great part of it by this means dissipated in the air. If they are of a sufficient thickness, the heat cannot penetrate so easily; and thus the inner part of the furnace preserves the heat of the fuel, and communicates it to the contained vessel. In the construction of a portable furnace, therefore, it will be convenient to have all parts of it six inches thick at least. This will also give it a sufficient degree of strength; and, as it is formed of several different peices, no inconvenience can follow from the weight of each of them taken separately.

In Boerhaave's chemistry, this furnace is represented as narrower at the bottom than at the top; but we cannot suppose any good reason for such a form, seeing a cylindrical one must answer every purpose much better, as allowing a larger quantity of air to pass through the fuel, and likewise not being so apt to be overturned as it necessarily must be where the upper part is considerably heavier than the lower. We have, therefore, given a representation of it as of a cylindrical form.

The furnace consists of five or more parts. C, represents the dome, or top of the furnace, with a short earthen funnel E for transmitting the smoke. B, B, B, are moveable cylinders of earth, each provided with a door D, D, D. In Boerhaave's chemistry these doors are represented as having iron hinges and latchets; but they may be formed to more advantage of square pieces of earth, having two holes in the middle, by which they may be occasionally taken out, by introducing an iron fork. In like manner, the domes and cylinders, Chemical Furnaces. cylinders, in Boerhaave's chemiſtry, are repreſented with iron handles; but they may be almoſt as eaſily taken off by the cheaper contrivance of having four holes in each, two directly oppoſite to one another, into which two ſhort forks may be introduced when the parts are to be ſeparated.

In the lowermoſt cylinder is to be placed an iron-grate, a little below the door, for ſupporting the fire. In the under part is a ſmall hole, big enough for introducing the pipe of a pair of good perpetual bellows when the fire is to be violently excited. Dr Lewis prefers the organ-bellows to any other kind.

When the bellows is uſed, the whole muſt ſtand upon a cloſe cylinder A, that the air may be confined, and made to paſs through the fuel. By having more bellows, the fire may be excited to a moſt intenſe degree. In this caſe, the pipe of every one of them muſt enter the cylinder B.

Each of the cylinders ſhould have, in its upper part a round hole, oppoſite to its door, for carrying off the ſmoke, by means of a pipe inſerted into it, when the furnace is uſed for diſtillations by the ſand-bath. Each cylinder ought likewiſe to have a ſemicircular cut in the oppoſite ſides, both above and below, that when the under cut of the upper cylinder is brought directly above the upper cut of the lower one, a perfect circle may be formed. Theſe are for giving a paſſage to the necks of retorts, when diſtillation by the retort is to be performed. The holes may be occaſionally filled with ſtopples made of the ſame materials with the body of the furnace.

The moſt convenient ſituation for a furnace of this kind would be under a chimney, the vent of which might be eaſily ſtopped up by a broad plate of iron, in which a hole ought to be cut for the reception of the earthen tube of the dome. By this means the uſe of a long tube, which at any rate muſt be very troubleſome, might be eaſily avoided, and a very ſtrong blaſt of air would paſs through the fuel. If it is found convenient to place the furnace at ſome diſtance from the chimney, a plate-iron pipe muſt be procured to fit the earthen pipe of the dome, and carry the ſmoke into the chimney. This pipe will alſo be of uſe, when the furnace is uſed for diſtillations by the ſand-bath; it muſt then be inſerted into the hole oppoſite to the door of any of the cylinders, and will convey away the ſmoke, while the mouth of the cylinder is totally covered with a ſand-pot.

601 Dr Lewis's portable furnaces.

For portable furnaces, Dr Lewis greatly recommends the large black crucibles, marked n° 60, on account of their reſiſting a violent heat, and being very eaſily cut by a knife or ſaw, ſo that doors, &c. may be formed in them at pleaſure. The bottom of one of theſe large ones being cut out, a grate is to be put into the narrow part of it. For grates, the doctor recommends caſt iron-rings, having each three knobs around them. Theſe knobs go into correſponding cavities of the outer rings, and the knobs of the outermoſt reſt on the crucible, which is to be indented a little to receive them, that ſo the grate may reſt the more firmly, and the furnace not be endangered from the ſwelling of the iron by heat. When this is to be made uſe of as a melting-furnace, and a violent heat to be excited, another crucible muſt be inverted on that which contains the fuel, which ſerves inſtead of the dome of the laſt mentioned furnace: and as whatever is ſaid of it muſt likewiſe be applicable to the two crucibles when placed above one another, we need give no farther deſcription of the doctor's portable furnace.

602 Objection to their uſe in ſome caſes.

No doubt, the great experience of Dr Lewis, in chemical matters muſt give very conſiderable weight to any thing he advances; and the warmth with which he recommends the furnaces muſt convince us, that he has found them abundantly anſwer the purpoſes of experiments. We cannot help thinking, however, that where a very great and laſting heat is to be given, the thickneſs, and even the *form*, of theſe crucibles, is ſome objection to their uſe. It is certain that ſuch a permanent, or, as the workmen call it, a *ſolid* heat, can never be given where the walls of a furnace are thin, as when they are of ſufficient thickneſs. They are alſo very apt to burſt with great heat; and, for this reaſon, Dr Lewis deſires his furnace to be ſtrengthened with copper hoops. This diſpoſition to burſt proceeds from the inner parts which are more intenſely heated than the outer, expanding more than theſe do, and conſequently burſting them. Hence the doctor deſires his furnace to be ſtrengthened alſo by putting it within another crucible of a larger ſize, and the intermediate ſpace to be filled up with a mixture of ſifted aſhes and water. For moſt chemical proceſſes, where only a ſmall degree of heat is requiſite, theſe furnaces anſwer beyond any thing that has hitherto been attempted. The whole is to be ſupported by an iron ring with three feet

2d 602 Dr Black's furnace deſcribed. Plate CXXXIII fig. 5, 8, 9.

Dr Black has contrived a furnace in which all theſe inconveniences are avoided. Two thick iron plates, above and below, are joined by a thinner plate, forming the body of the furnace, which is of an oval form. The upper part is perforated with two holes; the one A, pretty large, which is the mouth of the furnace, and which is of a circular form: the other behind it, B, of an oval form, and deſigned for faſtening the end of the vent which is ſcrewed down upon it. The undermoſt thick plate has only the large circular opening G near to the middle, but not altogether ſo, being nearer to one ſide of the ellipſe than the other, where the round hole in the top is placed; ſo that a line paſſing this circular hole has a little obliquity forwards. The aſh-pit C E is likewiſe made of a nelliptical form, and a very ſmall matter widened; ſo that the bottom of the furnace is received within the ellipſe. A little below, there is a border D that receives the bottom of the furnace; and except the holes of the damping-plate E, the parts are all cloſed by means of ſoft lute, upon which the body of the furnace is preſſed down; by which means the joining of the two parts, and of all the different pieces, are made quite tight; for the body, fire place, aſh-pit, vent, and grate, are all ſeparable from one another. As the furnace comes from the workman, the grate is made to apply to the outſide of the lower part. It conſiſts of a ring laid on its edge, and then bars likewiſe laid on their edges; and from the outer ring proceed four pieces of iron, by means of which it may be ſcrewed down; ſo it is kept out of the cavity of the furnace, and preſerved from the extremity of the heat. Thus it laſts much longer, and indeed hardly liable to any decay; for by being expoſed to the cool air, it is kept ſo cool, that it

Chemical Furnaces.

is never hurt by the heat of the fuel. The fides, which are made of plate iron muft be luted within, to confine the heat, and preferve them from its action.

603 How adapted to the various operations of chemiftry. To adapt this to the various operations of chemiftry, we may obferve, that for a melting furnace it is very convenient; we need only provide a cover for the opening above, which is made the door; and which being immediately over the grate, is convenient for introducing the fubftances to be acted upon, and for allowing us to look into the veffel and take it out. This cover may be a piece of tile, or two bricks rendered flat and fquare. Dr Black commonly ufes a kind of lid with a rim containing a quantity of lute; and to augment the heat, we may increafe the height of the vent. It can be employed in moft operations in the way of effaying; and the fituation of the door allows us to fee the fubftances very readily. It does not admit the introduction of the muffle; but can be employed in all thofe operations where the muffle is made ufe of; and in Cornwall in England fuch a furnace is made ufe of for effaying of metals. To preferve the fubftance from the contact of the fuel, they cut off about a third part of the length of a brick, and then put it on one end on the middle of the grate. They choofe their fuel of large pieces, that the air may have free paffage through it, and open a little of the door, which occafions a ftream of air to flow in; and this ftrikes upon the fubftance and produces the effect defired; fo that it may be ufed in the calcination of lead to convert it into litharge. It alfo anfwers very well in operations for producing vapour. If we defire to employ it in diftillations which require an intenfe heat, the earthen retort is to be fufpended by means of an iron ring having three branches ftanding up from it, and which hangs down about half a foot from the hole; fo that the bottom of the retort refts upon the ring, and is immediately hung over the fuel: and the opening between the mouth of the furnace and retort is filled up with broken crucibles and potfherds, which are covered over with afhes that tranfmit the heat very flowly; fo it anfwers for diftillations performed with the naked fire. Dr Black has fometimes caufed them be provided with a hole in the fide, from which the neck of the retort may be made to come out; and in this way has diftilled the phofphorus of urine, which requires a very ftrong heat. For diftillations with retorts performed with the fandbath, there is an iron pot fitted for the opening of the furnace, which is fet on and employed as a fand-pot. The vent of the furnace then becomes the door; and it anfwers very well for that purpofe; and is more eafily kept tight than if it were in the fide, and may be kept clofe with a lid of charcoal and clay. In like manner it anfwers well for the common ftill, which may be adapted to it; part of it being made to enter the open part of the furnace, and hang over the fire, as in Plate CXXXIII. fig. 8. and 9. that the bottom part of that ftill may be made to enter; and the vent becomes the door, by which frefh fuel may be added. Indeed it is feldom neceffary to add frefh fuel during any operation. In the ordinary diftillations it is never neceffary; and even in diftilling mercury, phofphorus, &c. it generally contains enough to finifh the operation; fo effectually is the heat preferved from lofs or diffipation, and fo very flow is the confumption of the fuel.

For luting this and other furnaces, the doctor finds nothing preferable to a fimple mixture of fand and clay. The proportions for ftanding the violence of fire are four parts of fand to one of clay; but when defigned for the lining of furnaces, he ufes fix or feven of fand to one of clay, the more effectually to prevent the contraction of the latter; for it is known from experiments, that clay, when expofed to a ftrong heat, contracts the more in proportion to its purity. The fand fettles into lefs bulk when wet, and does not contract by heat, which it alfo refifts as well as the clay itfelf. 604 Luting proper for his furnace.

Befides this outfide lining next the fire, Dr Black ufes another to be laid on next the iron of the furnace; and this confifts of clay mixed with a large portion of of charcoal duft. It is more fit for containing the heat, and is put next to the iron, to the thicknefs of an inch and a half. That it may be pretty dry when first put in, he takes three parts by weight of the charcoal duft, and one of the common clay, which muft be mixed together when in dry powder, otherwife it is very difficult to mix them perfectly. As much water is added as will form the matter into balls; and thefe are beat very firm and compact by means of a hammer upon the infide of the furnace. The other lute is then fpread over it to the thicknefs of about half an inch, and this is alfo beat folid by hammering; after which it is allowed to dry flowly, that all cracks and fiffures may be avoided: and after the body of the furnace is thus lined, the vent is fcrewed on and lined in the fame manner. It muft then be allowed to dry for a long time; after which a fire may be kindled, and the furnace gradually heated for a day or two. The fire is then to be raifed to the greateft intenfity; and thus the luting acquires a hardnefs equal to that of free-ftone, and is afterwards as lafting as any part of the furnace. 605 Method of applying the lute.

When furnaces are ufed in the large way, they are always built of brick, and each particular operation has a furnace allotted for itfelf. The melting-furnace, where very large quantities of matter are not to be melted at once, requires only to be built of brick in fuch a form as we have already defcribed; only, as it would perhaps be troublefome to procure a dome of the proper figure, the forepart of it may be left entirely open for the admiffion of melting veffels. The opening may be clofed up with bricks and earth during the operation. There is no neceffity for having the infide of a circular form; a fquare one will anfwer the purpofe equally well. According to the author of the Chemical Dictionary, when the internal diameter D C of fuch a furnace is 12 or 15 inches, the diameter of the tube G I 8 or 9 inches, and its height 18 or 20 feet, and when the furface is well fupplied with fuel, and extreme heat is produced; in lefs than an hour the furnace will be white and dazzling like the fun; its heat will be equal to the ftrongeft glafs-houfe furnace; and in lefs than two hours will be melted whatever is fufible in furnaces. The hotteft part is at H F, 4 or 6 inches above the grate. A plate-iron tube may be advantageoufly fupplied by a fhort chimney of bricks, built under a pretty high vent, fo as the whole may eafily be ftopped, except that paffage which tranfmits the fmoke of the furnace. By this means a very ftrong current of air will be made to pafs through the fuel. 2d 605 Melting furnace. Plate CXXXIV. fig. 2.

On this fubject Dr Black informs us, that Mr Pott of Berlin employs one almoft fimilar to the above, for 606 Mr Pott's melting furnace defcribed.

for making experiments on earthen ware; by which he ſhowed that many ſubſtances formerly rekoned infuſible, might nevertheleſs be melted by fire raiſed to a very intenſe degree; and that ſeveral of theſe bodies, when mixed together, form compounds which may be melted without any difficulty. From this a tube ariſes to ſome height, and there is an additional tube which may be put on to the height of above 10 feet. The fire-place is narrow below, but widens towards the middle, and contracts again at top, for the ſake of the veſſels which are put into it, and which are wider at top than at bottom. Thus the veſſel is equally heated, and there is room above for containing a quantity of fuel, which deſcends as faſt as it is conſumed. Different reaſons have been aſſigned for this form: thus Dr Boerhaave imagines that the melting furnace ſhould be made of a parabolic form, and Macquer, that it ſhould be in the form of an ellipſe; and that the crucible ſhould be placed in one of the foci, where they imagined the heat would be concentrated; but it is very plain, that the materials are ſuch as are not capable of reflecting the rays of heat in a regular manner; and even though they could do ſo, it would be to no purpoſe, becauſe the heat and light do not come from any ſingle point, but from a great number, ſtriking the furnace in all poſſible directions, and which muſt conſequently be reflected in directions as numerous. The furnace is made of iron lined with clay; and as it is difficult to beat out the iron into this roundiſh form, it may as well be made cylindrical; and it is eaſy to give the inſide what form we pleaſe by means of a luting of clay; neither need the dome have the roundiſh form, but may be ſimply made conical. The vent ſhould be made about two-thirds of the diameter of the furnace, or ſuch as will give an area of about one-half the grate. A ſmall portable furnace of this kind is very convenient for ordinary crucibles; the largeſt of which are only about four or five inches high; the wideſt part of the furnace may be beat out about 10 inches diameter; and when made of thin plate iron, and lined within, are very convenient, and may be heated at very little expence of fuel. But for heating much larger veſſels, it is proper to conſtruct them of brick, when they have pretty much the ſame form; only it is neceſſary to make them ſquare, and round on the inſide with a luting of ſand and clay. The top is generally made flat, and covered over with two or three bricks; the vent goes a little backwards, and then is raiſed to a proper height. Where the veſſel to be heated is very large, it is common to leave the front open for putting in the veſſel; and then to build it up with bricks, clay, and ſand; which can be eaſily pulled down again when the operation is over.

607 Reaſons for making the fire-place of a roundiſh form.

608 When bellows are neceſſary.

There are ſome caſes in which it is neceſſary to have a rapidity of inflammation even beyond what this furnace can give; and in theſe we have recourſe to bellows of various conſtructions, by which the air can be compreſſed and made to enter the fuel with great velocity. Theſe again are ſometimes wrought by water; but there is another machine which produces a greater effect, viz. the *water-blaſt* deſcribed by Lewis in his *Commercium Philoſoph. Technicum*.

609 In what caſes the eolipile may be made uſe of.

The eolipile too may be employed for driving air into fuel. The effect of this has been conſidered as a proof that air acts by its elaſticity in animating fuel, as an elaſtic fluid vapour from the eolipile produces, the ſame effect. But when we contrive to ſend ſteam inſtead of air, the ſame effect is not produced; and the true manner in which this inſtrument increaſes the inflammation is by driving air through the fuel: the ſteam from the veſſel ſpreading and mixing with the air, and driving it before it, makes it ſtrike upon the fuel.

Chemiſts have generally believed that a wide and high aſh-hole greatly increaſes the power of a melting furnace; but this advantage is found to be merely imaginary, as well as that of introducing the air through a long tube to the aſh-hole; unleſs where the furnace is placed in a cloſe room, ſo that it is neceſſary to furniſh a greater blaſt of air than can otherwiſe have acceſs.

For the form of the furnaces neceſſary in eſſaying and ſmelting of ores or making glaſs, ſee Essaying Glass, and Smelting. 610

Stills, ſand-pots &c. how to ſet.

When large ſtills, ſand-pots, &c. are to be fixed with a view to daily uſe, it is a matter of no ſmall conſequence to have them put up in a proper manner. The requiſites here are, 1. That the whole force of the fire ſhould be ſpent on the diſtilling veſſel or ſand-pot, except what is neceſſarily imbibed by the walls of the furnace. 2. That the veſſel ſhould be ſet in ſuch a manner as that they may receive heat even from the furnace walls; for a ſtill which contains any liquid can never be made ſo hot as a piece of dry brick. 3. It is abſolutely neceſſary that the force of the fire be not allowed to collect itſelf upon one particular part of the veſſel; otherwiſe that part will ſoon be deſtroyed. 3. The draught of air into furnaces of this kind ought to be moderate; only ſo much as will prevent ſmoke. If a ſtrong blaſt of air enters, not only a great part of the heat will be waſted by going up the chimney, but the outſide of the veſſel will be calcined every time the fire is kindled, and thus muſt be ſoon rendered unfit for uſe.

There are few of the common workmen that are capable of building furnaces properly; and it is very neceſſary for a chemiſt to know when they are properly done, and to make the workmen act according to his directions. As the ſtill, or whatever veſſel is to be fixed, muſt have a ſupport from the furnace on which it is built, it is evident the *whole* of its ſurface cannot be expoſed to the fire. For this reaſon many of theſe veſſels have had only their bottom expoſed to the fire, no more ſpace being left for the action of the heat, than the mere circular area of the ſtill bottom; and the fire paſſing directly through a hole in the back part of the building, which communicated with a chimney, and conſequently had a ſtrong draught, ſcarce ſpent any of its force on the ſtill, but went furiouſly up the chimney. By this means an extraordinary waſte of fuel was occaſioned; and that part of the ſtill-bottom which was next the chimney receiving the whole force of the flame, was ſoon deſtroyed. Attempts were made to remedy this inconvenience, by putting the fire ſomething forward, that it might be at greater diſtance from the chimney, and conſequently might not ſpend its force in the air. This too was found to avail very little. A contrivance was then fallen upon to make the vent paſs round the body of the ſtill in a ſpiral form. This was a conſiderable improvement; but had the inconvenience of making the fire ſpend itſelf uſeleſsly on the walls of the furnace, and beſides waſted that part of the ſtill which touched the

Chemical Furnaces.

the under part of the vent. A much better method is to build the back part of the furnace entirely close, and make the fire come out through a long narrow opening before; after which it passes out through a flue in the back and upper part of the furnace into the chimney.

The only convenience of this form is, that the vent must either be very wide, or it is apt to choak up with soot, which last is a very troublesome circumstance. If the vent is made very wide, a prodigious draught of air rushes through the fuel, and increases the heat to such a degree as to calcine the metal of which the still is made; and, on the other hand, nothing can be more disagreeable than to have the vent of a furnace stopped up with soot. These inconveniences, however, are totally avoided by making two small vents, one on each side of the distilling vessel, which may communicate with a chimney by means of two tubes either of plate-iron or formed with clay or bricks, which may be occasionally taken off if they happen to be choaked up. The vessel is to be suspended by three trunnions, so that the whole surface may be exposed to the fire, excepting a ring the thickness of a brick all round; so that a very strong heat will be communicated although the furnace draws but little. The two small vents on each side will draw the flame equally; and by this means the most equable heat can be preserved, and may be pushed so far as to make the whole bottom and sides of the vessel intensely red. Such a construction as this is more especially useful for sand-pots, and those which are used for distilling alkaline spirits from bones.

In the use of the furnaces hitherto described, the attendance of the operator is necessary, both for inspecting the processes, and for supplying and animating the fuel. There are some operations, of a slower kind, that require a gentle heat to be continued for a length of time; which demand little attendance in regard to the operations themselves, and in which, of consequence, it is extremely convenient to have the attendance in regard to the fire as much as possible dispensed with. This end has been answered by the furnace called *athanor*; but the use of it has been found attended with some inconveniences, and it is now gerally laid aside.

611 Lamp furnace.

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

Plate CXXXIV. fig. 8.

The lamp consists of a brass pipe 10 or 12 inches long, and about a quarter of an inch wide, inserted at one end into the reservoir of the oil, and turned up at the other to an elbow, like the bole of a tobacco-pipe, the aperture of which is extended to the width of near two inches. On this aperture is fitted a round plate, having 5, 6, or 7 small holes, at equal distances, round its outer part, into which are inserted as many pipes about an inch long: into these pipes are drawn threads of cotten, all together not exceeding what in the common lamps form one wick: by this division of the wick, the flame exposes a larger surface to the action of the air, the fuliginous matter is consumed and carried off, and the lamp burns clear and vivid.

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

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

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construct lamp-furnaces on their principles; though, on the whole, it is to be doubted whether they are preferable to the above construction or not.

Explanations of the Plates.

Plate CXXXIII. fig. 1. shows the figure of the still recommended by Dr Black; the bottom formed in such a manner as to go into his furnace. A, the body; B, the head; C C, the tube conveying the steam into the worm; D F, the figure of the worm; E, the worm-tub.

Fig. 2. A head taller than the common, proper for rectifying ardent spirits.

Fig. 3. Another kind of still for a common furnace, having a concave bottom for receiving the flame. A, the body; B, the head.

Fig. 4. Papin's digester. See CHEMISTRY. n° 567. A, the body; B B, the cross-bars; C D, the screw; E, the lid.

Fig. 5. The outer case of Dr Black's furnace without the luting. A, the body; B, the feet; I G, the opening at top.

Fig. 6. C, the grate of the same, with four projections, having holes in them to fasten it by nails to the inside of the furnace.

Fig. 7. A crooked funnel for putting matters into a retort without touching the sides or neck.

Fig. 8. Dr Black's furnace put together in readiness for chemical operations. A the mouth; B, the chimney; C, the door of the ash-hole. E, the registers for admitting air.

Fig. 9. A section of the same, showing its inside structure. F, the top-cover; G, the body, with part of the grate; D, the receptacle for the ashes; C, its door; E, the registers.

Fig. 10. An iron support for a crucible.

Fig. 11. The figure of a crucible.

Plate CXXXIV. fig. 1. Dr Boerhaave's portable furnace. See CHEMISTRY, n° 600.

Fig. 2. Macquer's melting-furnace. AA, the door of the ash-pit; B, the space betwixt the top of the ash-pit and fire-place; D C, the bars; G H E F, the fire-place; I, the funnel. *Ibid.* 2d n° 605.

Fig. 3. Dr Lewis's portable furnace fitted with a still, *Ibid.* n° 601, 602.

Fig. 4. Shows the figure of retorts of different kinds. A, the body; B, the neck.

Fig. 5. A matrass and alembic head, with a cucurbit and alembic head made of one piece. A, the body; B, the long neck of the matrass; C, the alembic head. A, the body of the cucurbit; B, the head; C, an opening in the head for putting in the matter to be distilled; D, a glass stopple fitted to the opening just mentioned; E, the opening of the cucurbit mouth.

Fig. 6. The pelican and cucurbit now in disuse. A, the body of the pelican; B, the head; C, an opening fitted with a stopple; D D, the arms. A, the body of the cucurbit; B, the head; C, the neck; D, the spout.

Fig. 7. A row of adopters or aludels.

Fig. 8. Dr Lewis's lamp-furnace. *Ibid.* n° 611.

PART II. PRACTICE.

SECT. I. *Salts.*

§ 1. *Of the* VITRIOLIC *Acid, and its Combinations.*

612 Never found pure.

THE vitriolic acid is never found pure, but always united with some proportion, either of phlogiston or metallic and earthy substances. Indeed there is scarce any kind of earth which does not contain some portion of this acid, and from which it may always some way or other be separable. When pure, the vitriolic acid appears in the form of a transparent colourless liquor. By distilling in a glass retort, the aqueous part arises, and the liquor which is left becomes gradually more and more acid. This operation is generally called the *rectification*, or *dephlegmation*, of the acid. After the distillation has gone on for some time, the water adheres more strongly to what remains in the retort, and cannot be forced over without elevating part of the acid along with it. The remaining acid, being also exceedingly concentrated, begins to lose its fluidity, and puts on the appearance of a clear oil. This is the state in which it is usually sold, and then goes by the name of *oil of vitriol*. If the distillation is still farther continued, with a heat below 600° of Fahrenheit's thermometer, the acid gradually loses more and more of its fluidity, till at last it congeals in the cold, and becomes like ice. In this state it is called the *icy oil of vitriol*. Such exceedingly great concentration, however, is only practised on this acid for curiosity. If the heat be suddenly raised to 600°, the whole of the acid rises, and generally cracks the receiver. Clear oil of vitriol is immediately turned black by an admixture of the smallest portion of inflammable matter.

613 Rectification. (margin note beside "gradually more and more acid")

614 Attracts moisture from the air.

The icy oil of vitriol, and even that commonly sold, attracts the moisture of the air with very great force. Newmann relates, that having exposed an ounce of this acid to the air, from September 1736 to September 1737, at the end of the twelvemonth it weighed seven ounces and two drachms; and thus had attracted from the air above six times its own weight of moisture. This quantity, however, seems extraordinary; and it is probable, that in so long a time some water had been accidentally mixed with it; for Dr Gould, professor at Oxford, who seems to have tried this matter fully, relates, that three drachms of oil of vitriol acquired, in 57 days, an increase only of six drachms and an half. The acid was exposed in a glass of three inches diameter; the increase of weight the first day was upwards of one drachm; in the following days less and less, till, on the fifty-sixth, it scarce amounted to half a grain. The liquor, when saturated with humidity, retained or lost part of its acquired weight according as the atmosphere was in a moist or dry state; and this difference was so sensible as to afford an accurate hygrometer. Hoffman having exposed an ounce and two scruples in an open glass-dish, it gained seven drachms and a scruple in 14 days.

615 Productive both of cold and heat.

This acid, when mixed with a large quantity of water, makes the temperature something colder than before; but if the acid bears any considerable proportion to the water, a great heat is produced, so as to make the vessel insupportable to the hand; and therefore ſuch mixtures ought very cautiouſly, or rather not at all, to be made in glaſs veſſels, but in the common ſtone-bottles, or leaden veſſels, which are not apt to be corroded by this acid. The greateſt heat is produced by equal parts of acid and water.

616 Quantity of alkali ſaturated by it.

Though the vitriolic acid unites itſelf very ſtrongly with alkalies, both fixed and volatile, it does not ſaturate near ſo much of the latter as of the former. A pound of oil of vitriol will ſaturate two of the common fixed alkali, but ſcarce one of volatile alkali. The ſpecific gravity of good oil of vitriol is to water as 17 to 8.

617 Effects on the human body.

If the concentrated acid is applied ſlightly and ſuperficially to the ſkin of a living animal, it raiſes a violent burning heat and pain; but a larger quantity preſſed on, ſo as to prevent the ingreſs of aerial moiſture, occaſions little pain or eroſion. If diluted with a little water, it proves corroſive in either caſe. Largely diluted with water, this acid is employed medicinally for checking putrefaction, abating heat, and quenching thirſt; in debilities of the ſtomach, and heartburn. To perſons of weak and unſound lungs, to women who give ſuck, to hydropic or emaciated perſons, it is injurious. Some recommend it as a collyrium for ſore eyes; but as it coagulates the animal juices, corroding and indurating the ſolids, it ſeems very unfit for being applied to that tender organ.

618 Difficulty of procuring it by itſelf.

The vitriolic acid is ſo much uſed in different arts and manufactures, that the making of it has become a trade by itſelf; and the procuring it in plenty, and at a cheap rate, would be a very advantageous piece of knowledge to any perſon who could put it in practice. This, however, is very far from being eaſily done; for though it exiſts in almoſt every mineral ſubſtance, the attraction betwixt this acid and the baſes with which it unites, is found to be ſo ſtrong, that we can only decompoſe ſuch combinations by preſenting another ſubſtance to the acid, to which it has a greater attraction than that one wherewith it is joined. Thus the firſt combination is indeed diſſolved, but we have another from which it is eqally difficult to extricate the acid by itſelf. Thus, if we want to diſengage the vitriolic acid from any metallic ſubſtance, ſuppoſe iron, this may be eaſily done by throwing a calcareous earth into a ſolution of green vitriol. We have now a compound of vitriolic acid with the calcareous earth, which is known by the name of *gypſum* or *ſelenites*. If we want to decompoſe this we muſt apply a volatile or or a fixed alkali; and the reſult of this will conſtantly be a new combination, which we are as unable to decompoſe, and indeed more ſo, than the firſt. There are two general methods which have been in uſe for procuring the vitriolic acid in ſuch quantity as to ſupply the demands of trade. The one is from pyrites, and the other from ſulphur.

I. From *Pyrites*, with the making of Copperas, and obtaining the pure Oil of Vitriol from it.

619 Pyrites, where found.

Pyrites are found in large quantity in the coal-mines of England, where moſt of the copperas is made. They are very hard and heavy ſubſtances, having a kind of braſſy appearance, as if they contained that metal; and hence they are called *braſſes* by the workmen. A very large quantity of theſe is collected, and ſpread out upon a bed of ſtiff clay to the depth of three feet. After being ſome time expoſed to the air, the uppermoſt ones loſe their metallic appearance, ſplit, and fall to powder. The heaps are then turned, the under part uppermoſt, ſo as to expoſe freſh pyrites to the air. When they are all reduced to powder, which generally requires three years, the liquor, which is formed by the rain-water running from ſuch a large maſs, becomes very acid, and has likewiſe a ſtyptic vitriolic taſte. It is now conveyed into large ciſterns lined with clay, whence it is pumped into a very large flat veſſel made of lead. This veſſel, which contains about 15 or 20 tons of liquor, is ſupported by caſt-iron plates about an inch thick, between which and the lead a bed of clay is interpoſed. The whole reſts upon narrow arches of brick, under which the fire is placed. Along with the liquor, about half a ton or more of old iron is put into the evaporating veſſel. The liquor, which is very far from being ſaturated with acid, acts upon the iron, and, by repeated filling up as it evaporates, diſſolves the whole quantity. By the time this quantity is diſſolved, a pellicle is formed on the ſurface. The fire is then put out; and as ſuch a prodigious quantity of liquor does not admit of filtration, it is left to ſettle for a whole day, and then is let off by a cock placed a little above the bottom of the evaporating veſſel, ſo as to allow the impurities to remain behind. It is conveyed by wooden ſpouts to a large leaden ciſtern, five or ſix feet deep, ſunk in the ground, and which is capable of containing the whole quantity of liquor. Here the copperas cryſtallizes on the ſides, and on ſticks put into the liquor. The cryſtallization uſually takes up three weeks. The liquor is then pumped back into the evaporating veſſel; more iron, and freſh liquor from the pyrites, are added; and a new ſolution takes place.

Copperas is uſed, in dyeing, for procuring a black colour; and is an ingredient in making common ink. It is alſo uſed in medicine as a corroborant, under the name of *ſalt of ſteel*; but before it is uſed with this intention, it is rediſſolved in water, and cryſtallized, with the addition of a little pure oil of vitriol. Whether it is at all mended by this ſuppoſed purification, either in appearance or quality, is very doubtful.

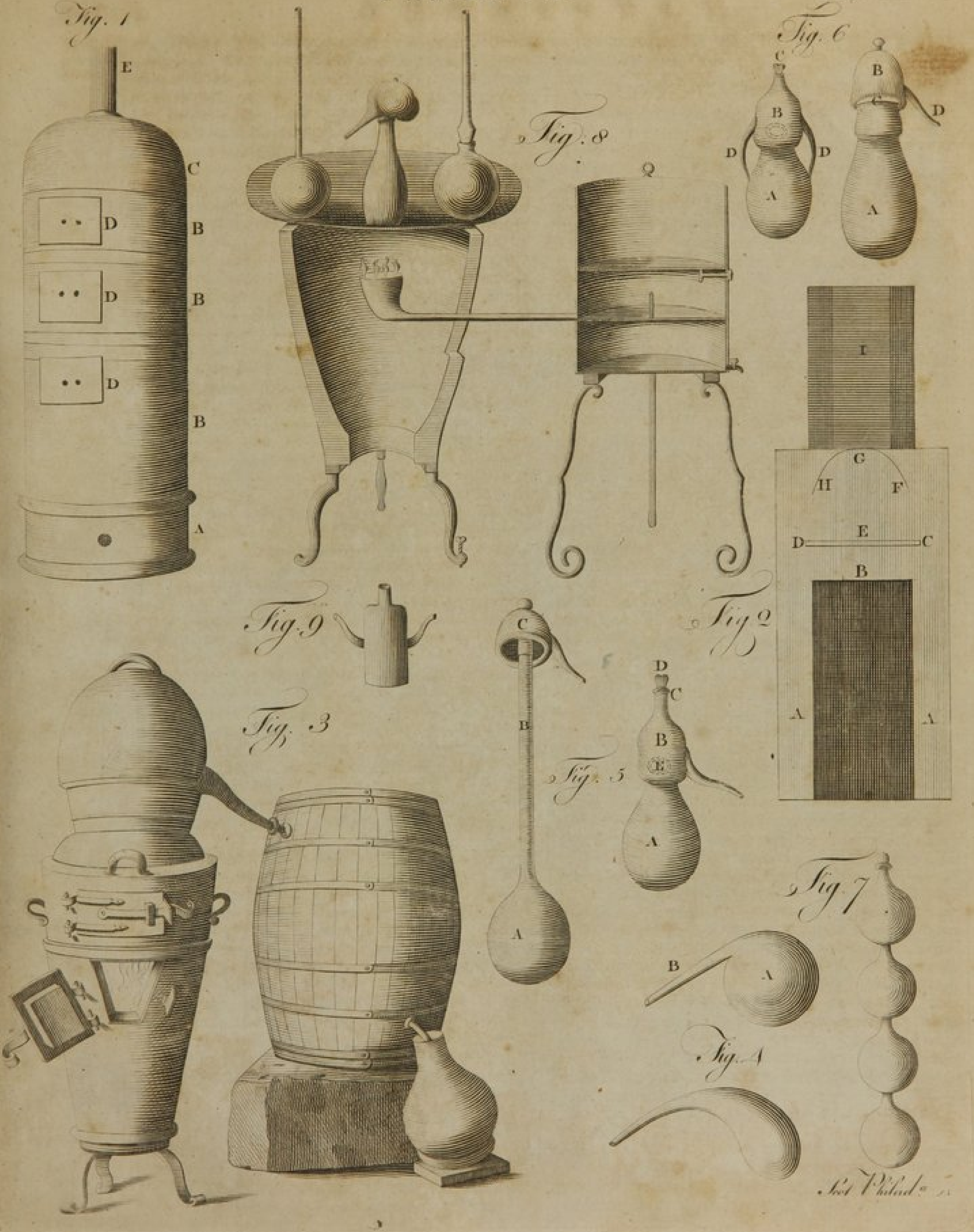
This proceſs furniſhes us firſt with a very impure vitriolic acid, which could not be applied to any uſeful purpoſe; afterwards with an imperfect neutral ſalt, called *green vitriol*, which is applicable to ſeveral purpoſes where the pure acid itſelf could not be uſed; but ſtill the acid by itſelf is not to be had without a very troubleſome operation.

620 Diſtillation of vitriolic acid from copperas.

Though this acid adheres very ſtrongly to iron, it is capable of being expelled from it by fire; yet not without a very violent and long-continued one. If we attempt to diſtil green vitriol in a retort, it ſwells and boils in ſuch a manner by the great quantity of water contained in its cryſtals, that the retort will almoſt certainly crack; and though it ſhould not, the ſalt would be changed into an hard ſtony maſs, which the fire could never ſufficiently penetrate ſo as to extricate the acid. It muſt therefore be calcined previous to the diſtillation. This is beſt done in flat iron-pans, ſet over a moderate fire. The ſalt undergoes the watery

CHEMISTRY

Plate CXXXIV



Vitriolic acid and its combinations.

tery fusion, (See FUSION); after which it becomes opaque and white. By a continuance of the fire, it becomes brown, yellow, and at last red. For the purposes of distillation, it may be taken out as soon as it has recovered its solidity.

The dry vitriol, being now reduced to powder, is to be put into an earthen retort, or rather long neck (a kind of retort where the neck issues laterally, that the vapours may have little way to ascend), which it may nearly fill. This retort must be placed in a furnace capable of giving a very strong heat, such as the melting furnace we have already described. A large receiver is to be fitted on; and a small fire made in the furnace to heat the vessels gradually. White fumes will soon come over into the receiver, which will make the upper part warm. The fire is to be kept of an equal degree of strength, till the fumes begin to disappear, and the receiver grows cool. It is then to be increased by degrees; and the acid will become gradually more and more difficult to be raised, till at last it requires an extreme red, or even white, heat. When nothing more will come over, the fire must be suffered to go out, the receiver be unluted, and its contents poured into a bottle fixed with a glass stopper. A sulphureous and suffocating fume will

621 Preservatives of wood.

come from the liquor, which must be carefully avoided. In the retort, a fine red powder will remain, which is used in painting, and is called *colcothar of vitriol*. It is useful on account of its durability; and, when mixed with tar, has been employed as a preservative of wood from rotting; but Dr Lewis prefers finely powdered pit-coal. As a preservative for masts of ships, he recommends a mixture of tar and lampblack; concerning which he relates the following anecdote.

"I have been favoured by a gentleman on board of a vessel in the East-Indies, with an account of a violent thunder-storm, by which the main-mast was greatly damaged, and whose effects on the different parts of the mast were pretty remarkable. All the parts which were greased or covered with turpentine were burst in pieces: those above, between, and below the greased parts, as also the yard-arms, the round-top or scaffolding, coated with tar and lamp-black, remained unhurt."

622 Rectification.

Oil of vitriol, when distilled in this manner, is always of a black colour, and must therefore be rectified by distillation in a glass retort. When the acid has attained a proper degree of strength, the blackness either flies off, or separates and falls to the bottom, and the liquor becomes clear. The distillation is then to be discontinued, and the clear acid which is left in the retort kept for use.

This was the first method by which the vitriolic acid was obtained; and from its being distilled from vitriol has ever since retained the name of *oil of vitriol*. Green vitriol is the only substance from which it is practicable to draw this acid by distillation; when combined with calcareous earths, or even copper (though to this last it has a weaker attraction than to iron), it resists the fire most obstinately. When distillation from vitriol was practised, large furnaces were erected for that purpose, capable of containing an hundred long necks at once: but as it has been discovered to be more easily procurable from sulphur, this method has been laid aside, and it is now needless to describe these furnaces.

Vitriolic acid and its combinations.

II. To procure the Vitriolic Acid from *Sulphur*.

623 Quantity of acid in sulphur.

This substance contains the vitriolic acid in such plenty, that every pound of sulphur, according to Mr Kirwan's calculation, contains more than one-half of pure acid; which being in a state perfectly dry, is consequently of a strength far beyond that of the most highly rectified oil of vitriol. Common oil of vitriol requires to be distilled to one-fourth of its quantity before it will coagulate when cold; and even in this state it undoubtedly contains some water. No method, however, has as yet been fallen upon to condense all the steams of burning sulphur, at least in the large

624 Quantity produced from it.

way, nor is any other profitable way of decomposing sulphur known than that by burning; and in this way the most successful operators have never obtained more than 14 ounces of oil from a pound of sulphur.

625 Methods of obviating the difficulties in this process.

The difficulties here are, that sulphur cannnot be burnt but in an open vessel; and the stream of air, which is admitted to make it burn, also carries off the acid which is emitted in the form of smoke. To avoid this, a method was contrived of burning sulphur in large glass globes, capable of containing an hogshead or more. The fume of the burning sulphur was then allowed to circulate till it condensed into an acid liquor. A greater difficulty, however, occurs here; for though the sulphur burns very well, its steams will never condense. It has been said, that the condensation is promoted by keeping some warm water continually smoking in the bottom of the globe; and even Dr Lewis has asserted this: but the steam of warm water immediately extinguishes sulphur, as we have often experienced; neither does the fume of burning sulphur seem at all inclinable to join with water, even when forced into contact with it. As it arises from the sulphur, it contains a quantity of phlogiston, which in a great measure keeps it from uniting with water; and the desideratum is not something to make the sulphur burn freely, but to deprive the fumes of the phlogiston they contain, and render them miscible with water. For this purpose nitre has been advantageously used. This consumes a very large quantity of the phlogiston contained in sulphur, and renders the acid easily condensible: but it is plain that few of the fumes, comparatively speaking, are thus deprived of the inflammable principle; for the vessel in which the sulphur and nitre are burnt, remains filled with a volatile and most suffocating fume, which extinguishes flame, and issues in such quantity as to render it highly dangerous to stay near the place. It has been thought that nitre contributes to the burning of the sulphur in close vessels; but this too is a mistake. More sulphur may be burnt in an oil of vitriol globe without nitre than with it, as we have often experienced; for the acid of the sulphur unites with the alkaline basis of the nitre, and forms therewith an uninflammable compound, which soon extinguishes the flame, and even prevents a part of the sulphur from being burnt either at that time or any other.

626 Effervescence between the nitrous and sulphureous fumes.

In the condensation of the fumes of sulphur by means of nitre, a remarkable effervescence happens, which naturally leads us to think that the condensation is produced by some struggle between the vitriolic and

Vitriolic acid and its combinations.

nitrous acids.—Dr Lewis is of opinion, that the acid thus obtained is perfectly free from an admixture of the nitrous acid: but in this he is certainly mistaken; for, on rectifying the acid produced by sulphur and nitre, the first fumes that come over are red, after which they change their colour to white. How the nitrous acid should exist in the liquor, indeed, does not appear; for this acid is totally destructible by deflagration with charcoal: but it does not follow, that because the nitrous acid is destroyed when deflagrated with charcoal, it must likewise be so if deflagrated with sulphur. Indeed it certainly is not; for the clyssus of nitre made with sulphur is very different from that made with charcoal.

The proportions of nitre to the sulphur, used in the large oil of vitriol works, are not known, every thing being kept as secret as possible by the proprietors. Dr Lewis reckons about six pounds of nitre to an hundred weight of sulphur; but from such experiments as we have made, this appears by far too little. An ounce and an half, or two ounces, may be advantageously used to a pound of sulphur. In greater proportions, nitre seems prejudicial.

627 Lead vessels, an improvement.

A very great improvement in the apparatus for making oil of vitriol, lies in the using lead vessels instead of glass globes. The globes are so apt to be broken by accident, or by the action of the acid upon them, that common prudence would suggest the use of lead to those who intend to prepare any quantity of vitriolic acid, as it is known to have so little effect upon the metal. The leaden vessels, according to the best accounts we have been able to procure, are cubes of about three feet, having on one side a door about six inches wide. The mixture of sulphur and nitre is placed in the hollow of the cube, in an earthen saucer, set on a stand made of the same materials. The quantity which can be consumed at once in such a vessel is about two ounces. To prevent the remains from sticking to the saucer, it is laid on a square bit of brown paper. The sulphur being kindled, the door is to be close shut, and the whole let alone for two hours. In that time the fumes will be condensed. The door is then to be opened; and the operator must immediately retire, to escape the suffocating fumes which issue from the vessel. It will be an hour before he can safely return, and introduce another quantity of materials, which are to be treated precisely in the same manner.

Where oil of vitriol is made in large quantities, the slowness of the operation requires a great number of globes, and constant attendance day and night. Hence the making of this acid is very expensive: The apparatus for a large work usually costs L.1500. sterling.

Vitriolic Acid combined,

628 Vitriolated tartar.

I. *With Fixed Alkali.* Dilute a pound of oil of vitriol with ten times its quantity of water; dissolve also two pounds of fixed alkaline salt in ten pounds of water, and filter the solution. Drop the alkali into the acid as long as any effervescence arises; managing matters so that the acid may prevail. The liquor will now be a solution of the neutral salt, called *vitriolated tartar*, which may be procured in a dry form, either by exsiccation or crystallization. In case the latter method is made use of, some more alkali must be added when it is set to evaporate, for this salt crystallizes best in an alkaline liquor.

Other methods, besides that above described, have been recommended for preparing vitriolated tartar; particularly that of using green vitriol instead of the pure vitriolic acid. In this case the vitriol is decomposed by the fixed alkali: but as the alkali itself dissolves the calx of iron after it is precipitated, it is next to impossible to procure a pure salt by such a process; neither is there occasion to be solicitous about the preparation of this salt by itself, as the materials for it are left in greater quantity than will ever be demanded, after the distillation of spirit of nitre. 629 [630] Different methods of preparing vitriolated tartar.

631 Uses.

Vitriolated tartar is employed in medicine as a purgative; but is not at all superior to other salts which are more easily prepared in a crystalline form. It is very difficultly soluble in water, from which proceeds the difficulty of crystallizing it: for if the acid and alkali are not very much diluted, the salt will be precipitated in powder, during the time of saturation.—It is very difficult of fusion, requiring a strong red heat; but, notwithstanding its fixedness in a violent fire, it arises with the steam of boiling water in such a manner as to be almost totally dissipated along with it by strong boiling.—This salt has been used in making glass; but with little success, as the glass wherein it is an ingredient always proves very brittle and apt to crack of itself.

632 Glauber's salt.

If, instead of the vegetable fixed alkali, the vitriolic acid is saturated with the fossile one called the *salt of Soda*, a kind of neutral salt will be produced, having very different properties from the vitriolated tartar. This compound is called *Glauber's salt*. It dissolves easily in water, shoots into long and beautiful crystals, which contain a large quantity of water, in consequence of which they undergo the aqueous fusion when exposed to heat. They are also more easily fusible than vitriolated tartar.—This kind of salt was formerly much recommended as a purgative, and from its manifold virtues was intitled by its inventor *sal mirabile*. It is, however, found to possess no virtue different from that of other purgative salts: and its use is, in many places, entirely superseded by a salt prepared from the *bittern*, or liquor which remains after the crystallization of sea-salt, which shall be afterwards described.

633 Glauber's secret salt ammoniac.

II. *With volatile alkali.* Take any quantity of volatile alkaline spirit; that prepared with quicklime is perferable to the other, on account of its raising no effervescence. Drop into this liquor, contained in a bottle, diluted oil of vitriol, shaking the bottle after every addition. The saturation is known to be complete by the volatile smell of the alkali being entirely destroyed. When this happens, some more of the spirit must be added, that the alkali may predominate a little, because the excess will fly off during the evaporation. The liquor, on being filtered and evaporated, will shoot into fine fibrous plates like feathers. This salt, when newly prepared, has a sulphureous smell, and a penetrating pungent taste. It readily dissolves in water, and increases the coldness of the liquor; on standing for a little time, it begins to separate from the water, and

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Vitriolic acid and its combinations.

vegetate, or ariſe in effloreſcences up the ſides of the glaſs. It eaſily melts in the fire; penetrates the common crucibles; and if ſublimed in glaſs veſſels, which requires a very conſiderable heat, it always becomes acid, however exactly the ſaturation was performed.

This ſalt has been dignified with the names of *Glauber's ſecret ſal ammoniac*, or *philoſophic ſal ammoniac*, from the high opinion which ſome chemiſts have entertained of its activity upon metals: but from Mr Pott's experiments, it appears, that its effects have been greatly exaggerated. It diſſolves or corrodes in ſome degree all thoſe metals which oil of vitriol diſſolves, but has no effect upon thoſe on which that acid does not act by itſelf.

634 Properties of the ſalts.

Gold is not touched in the leaſt, either by the ſalt in fuſion, or by a ſolution of it: the ſalt added to a ſolution of gold in aqua-regia occaſions no precipitation or change of colour. On melting the ſalts with inflammable matters, it forms a ſulphureous compound, which diſſolves gold in fuſion, in the ſame manner as compoſitions of ſulphur and fixed alkaline ſalt. Melted with ſilver, it corrodes it into a white calx, which partially diſſolves in water: it likewiſe precipitates ſilver from its ſolution in aquafortis. It acts more powerfully on copper; elevates a part of the metal in ſublimation, ſo as to acquire a bluiſh colour on the ſurface; and renders the greateſt part of the reſiduum ſoluble in water. This ſolution appears colourleſs, ſo that it could not be ſuppoſed to hold any copper; but readily diſcovers that it abounds with that metal, by the blue colour it acquires on an addition of volatile alkali, and the green calx which fixed alkalies precipitate. In evaporation it becomes green without addition. Iron is corroded by this ſalt in fuſion, and diſſolved by boiling in a ſolution of it. Zinc diſſolves more freely and more plentifully. Lead unites with it, but does not become ſoluble in water. Tin is corroded, and a part of the calx is ſoluble in boiling water. Of regulus of antimony alſo a ſmall portion is made ſoluble. Alkalies precipitate from the ſolution a bluiſh powder. Calcined biſmuth-ore treated with its equal weight of the ſalt, partly diſſolved in water into a pale red liquor, which became green from heat, in the ſame manner as tinctures made from that ore by aqua-regia. The undiſſolved part yielded ſtill, with frit, a blue glaſs. On treating manganeſe in the ſame manner, aluminous cryſtals were obtained: the undiſſolved part of the manganeſe gave ſtill a violet colour to glaſs.

635 Gypſum.

III. *With Calcareous Earth.* This combination may be made by ſaturating diluted oil of vitriol with chalk in fine powder. The mixture ought to be made in a glaſs; the chalk muſt be mixed with a pretty large quantity of water, and the acid dropped into it. The glaſs muſt be well ſhaken after every addition, and the mixture ought rather to be over ſaturated with acid; becauſe the ſuperfluous quantity may afterwards be waſhed off; the *ſelenite*, as it is called, or *gypſum*, having very little ſolubility in water.

This combination of vitriolic acid with chalk or calcareous earth, is found naturally in ſuch plenty, that it is ſeldom or never made, unleſs for experiment's ſake, or by accident. Mr Pott indeed ſays, that he found ſome ſlight differences between the natural and artificial gypſum, but that the former had all the eſſential properties of the latter.

The natural gypſums are found in hard, ſemitranſparent maſſes, commonly called *alabaſter*, or *plaſter of Paris*. (See Alabaster, Gypsum, and Plaster.) By expoſure to a moderate heat, they become opaque, and very friable. If they are now reduced to fine powder, and mixed with water, they may be caſt into moulds of any ſhape: they very ſoon harden without ſhrinking; and are the materials whereof the common white images are made. This property belongs likewiſe to the artificial gypſum, if moderately calcined. 636

Beaume's obſervations.

Mr Beaumé has obſerved, that gypſum may be diſſolved in ſome meaſure by acids; but is afterwards ſeparable by cryſtallization in the ſame ſtate in which it was before ſolution, without retaining any part of the acids. This compound, if long expoſed to a pretty ſtrong heat, loſes great part of its acid, and is converted into quicklime. In glaſs veſſels it gives over no acid with the moſt violent fire. It may be fuſed by ſuddenly applying a very intenſe heat. With clay it ſoon melts, as we have obſerved when ſpeaking of the materials for making crucibles. A like fuſion takes place when pure calcareous earth is mixed with clay; but gypſum bubbles and ſwells much more in fuſion with clay than calcareous earth.

From natural gypſum we ſee that vitriolated tartar may be made, in a manner ſimilar to its preparation from green vitriol. If fixed alkaline ſalt is boiled with any quantity of gypſum, the earth of the latter will be precipitated, and the acid united with the alkali. If a mild volatile alkali is poured on gypſum contained in a glaſs, and the mixture frequently ſhaken, the gypſum will in like manner be decompoſed, and a *philoſophic* ſal ammoniac will be formed. With the cauſtic volatile alkali, or that made with quicklime, no decompoſition enſues. 637

Alum of the ancients different from ours.

IV. *With Argillaceous Earth.* The produce of this combination is the aſtringent ſalt called *alum*, much uſed in dyeing and other arts. It has its name from the Latin word *alumen* called *στυπτηρια* by the Greeks; though by theſe words the ancients expreſſed a ſtalactitic ſubſtance containing very little alum, and that entirely enveloped in a vitriolic matter. The alum uſed at preſent was firſt diſcovered in the oriental parts of the world; though we know not when, or on what occaſion. One of the moſt ancient alum-works of which we have any account was that of *Roccho*, now Edeſſa, a city of Syria: and from this city was derived the appellation of *Roch-alum*; an expreſſion ſo little underſtood by the generality, that it has been ſuppoſed to ſignify *rock-alum*. From this, and ſome works in the neighbourhood of Conſtantinople, as well as at Phocaea Nova, now Foya Nova, near Smyrna, the Italians were ſupplied till the middle of the 15th century, when they began to ſet up works of a ſimilar kind in their own country. The firſt Italian alum-work was eſtabliſhed about 1459 by Bartholomew Perdix, or Pernix, a Genoeſe merchant, who had diſcovered the proper matrix, or ore of alum, in the iſland of Iſchia. Soon after the ſame material was diſcovered at Tolfa by John de Caſtro, who had viſited the alum manufactories at Conſtantinople. Ha-

638 Whence the name of rock alum is derived.

639 Alum-works ſet up in Italy.

Vitriolic acid and its combinations.

ving obferved the ilex aquilifolium to grow in the neighbourhood of the Turkifh manufactories, and finding the fame near Tolfa, he concluded that the materials for alum were to be found there alfo; and was quickly confirmed in his fufpicions by the tafte of the ftones in the neighbourhood. Thefe alum-works profpered exceedingly, and their fuccefs was augmented by an edict of Pope Pius II. prohibiting the ufe of foreign alum.

640 In Spain, England, and Sweden.

In the 16th century an alum manufactory was erected at Alamaron, in the neighbourhood of Carthagena, where it ftill continues. Several others were erected in Germany; and in the reign of Queen Elizabeth one was erected in England by Thomas Chaloner. The preparation of this falt was not known in Sweden till the 17th century.

641 Its component parts firft difcovered by Meff. Boulduc and Geoffroy.

The component principles of this falt were long unknown; but at laft Meffrs Boulduc and Geoffroy difcovered, that it confifted of argillaceous earth fuperfaturated with vitriolic acid. This is confirmed by the experiments of other chemifts. It is found to redden the tincture and paper of turnfole; and on taking away the fuperabundant acid, it lofes its folubility and all the other properties of alum.

642 Miftake of Morveau detected by Mr Kirwan.

Mr Morveau, indeed, will not admit of a fuperabundance of acid in alum, which he thinks would neceffarily be feparated by edulcoration and cryftallization; and he is of opinion with Mr Kirwan, that the turning vegetable juices red is not any unequivocal fign of the prefence of an acid. In the prefent cafe, however, we certainly know that there is a fuperabundance of acid, and that a certain portion of the vitriolic acid adheres to the clay lefs tenacioufly than the remainder.

643 Alum deprived of its fuperfluous acid infoluble in water.

If we put a piece of iron into a folution of alum, it will attract this portion of acid; and the vitriolated clay when deprived of the fuperfluous quantity, will fall down to the bottom in an infoluble powder.

Alum in its ordinary ftate contains a confiderable quantity of water, and cryftallizes by proper management into octohedral and perfectly tranfparent and colourlefs cryftals. When expofed to a moderate fire, it melts, bubbles, and fwells up; being gradually changed into a light, fpongy, white mafs, called *burnt alum*. This, with the addition of fome vitriolic acid, may be cryftallized as before. The principles it contains, therefore, are water, vitriolic acid, and argillaceous earth.

644 Bergman's method of finding the ingredients and their proportions.

The proportions may be afcertained in the following manner. 1. The water and fuperfluous vitriolic acid may be diffipated by evaporation, or rather diftillation; and the lofe of weight fuftained by the falt, as well as the quantity of liquid which comes over into the receiver, fhows the quantity of aqueous phlegm and unfaturated acid. 2. By combining this with as much cauftic fixed alkali as is fufficient to faturate the acid which comes over, we know its proportion to the water; and by rediftilling this new compound, we have the water by itfelf.

645 Difficulty in obtaining the pure earth of alum.

3. The earth may be obtained by precipitation with an alkali in its cauftic ftate, either fixed or volatile: but this part of the procefs is attended with confiderable difficulty; for the alkalies firft abforb the fuperfluous acid, after which the earth combined to faturation with the acid falls to the bottom, and the digeftion with the alkaline falt muft be continued for a very confiderable time before the acid is totally feparated. By analyfing alum in this manner, Mr Bergman determined the principles of alum to be 38 parts of vitriolic acid, 18 of clay, and 44 of water, to 100 of the cryftallized falt.

Vitriolic acid and its combinations.

646 Proportions of ingredients according to Mr Bergman.

647 Whether the earth of alum be a pure clay or not.

It has been a queftion among chemifts, whether the earth of alum is to be confidered as a pure clay or not. The falt was extracted from common clay by Meffrs Hellot and Geoffroy. The experiment was repeated with fuccefs by Mr Pott; but he feemed to confider it rather as the production of a new fubftance during the operation, than a combination of any principle already exifting with the vitriolic acid.

648 Component parts of all kinds of clay inveftigated by Margraaf.

Margraaf, however, from fome very accurate experiments, demonftrated, that all kinds of clay confift of two principles mechanically mixed: one of which conftantly is the pure earth of alum. This opinion is efpoufed by Bergman; who concludes, that fince an equal quantity of it may be extracted from clay by all the acids, it can only be mixed with thefe clays; for if it was generated by the menftrua during the operation, it muft be procured in different quantities, if not of different qualities alfo, according to the difference of the folvents made ufe of. Notwithftanding this, the matter feems to be rendered fomewhat obfcure by an experiment of Dr Lewis.

649 Lewis's experiment, tending to fhow that clay undergoes fome change in being converted into earth of alum.

"Powdered tobacco-pipe clay (fays he) being boiled in a confiderable quantity of oil of vitriol, and the boiling continued to drynefs, the matter when cold difcovers very little tafte, or only a flight acidulous one. Expofed to the air for a few days, the greateft part of it was changed into lanuginous efflorefcences tafting exactly like alum. The remainder, treated with frefh oil of vitriol, in the fame manner exhibits the fame phenomena till nearly the whole of the clay is converted into an aftringent falt." Hence he concludes, that the clay is in fome degree changed before the aluminous falt is produced. Without this fuppofition, indeed, it is difficult to fee why the falt fhould not be produced immediately by the combination of the two principles.

650 Solubility of alum in warm and in cold water.

An hundred parts of cryftallized alum requires, according to Mr Bergman, in a mean heat 1412 parts of diftilled water, but in a boiling heat only 75 of the fame parts for its folution. The fpecific gravity of alum, when computed from the increafe of bulk in its folution, is 2.071 when the air-bubbles are abftracted; but if they are fuffered to remain, it is no more than 1.757. Thefe bubbles confift of aerial acid, but cannot be removed by the air-pump, though they fly off on the application of heat.

651 Bergman's account of the Swedifh ores of alum.

The ores from which alum is prepared for fale, according to Mr Bergman, are of two kinds: one containing the alum already formed, the other its principles united by roafting.

652 Component parts of the aluminous fchift.

What he calls the aluminous fchift, is nothing but an argillaceous fchift impregnated with a dried petroleum, from whence the oil is eafily extracted by diftillation; but by applying proper menftrua it difcovers feveral other ingredients, particularly an argillaceous martial fubftance, frequently amounting to ⅔ of the whole; a filiceous matter amounting to ¼; and commonly alfo a fmall proportion of calcareous earth and magnefia; the reft being all pyritous.

653 How changed by roafting.

By roafting this ore the bituminous part is deftroyed and the pyrites decompofed; on which part of the vitriolic acid adheres to the iron of the pyrites, and the reft to the pure clay of the fchift, forming green vitriol with the former, and alum with the latter. If any calcareous earth or magnefia are prefent, gypfum and Epfom falt will be produced at the fame time. No falt is obtained

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by lixiviating this ſchiſt before calcination, though Mr Bergman thinks nothing more is neceſſary for the production of the ſalt but the preſence of a pyrites. This, he tells us, is generally diſperſed through the maſs in

654 The preſence of pyrites only neceſſary for the production of alum.

form of very minute particles, though it ſometimes appears in ſmall nuclei. The goodneſs of the ore, therefore, depends on the proper proportion of the pyrites to the clay, and its equal diſtribution through the whole. The moſt denſe and ponderous is moſt eſteemed, while that which contains ſo much pyrites as to be viſible is rejected as having too much iron. The ore which produces leſs than four pounds of alum from 100 of the ore does not pay the expence of manufacturing in Sweden. Sometimes this kind of ore produces ſalts without the application of fire; but this muſt be attributed to a kind of ſpontaneous calcination.

655 Ores containing alum ready formed, only to be met with in volcanic countries.

That ſpecies of ore which contains the principles already united into alum, according to Mr Bergman, is to be met with only in volcanic countries; and of this kind are the principal Italian ores of alum, particularly that employed at Tolfa near Cincelles, for boiling the Roman alum. Mr Monnet, however, is of opinion, that even this ore does not contain alum perfectly formed, but a combination of nearly equal parts of clay and ſulphur, which by expoſure to air during calcination, is converted into alum. He found a little

656 Aluminous ore at Solfatara in Italy.

martial earth alſo contained in it, to which he aſcribes the reddiſh colour of that alum. The aluminous ore at Solfatara in Italy conſiſts of old lava whitened by the phlogiſticated vitriolic acid. The clay thus becomes a component part of the aluminous ſalt, and the maſs effloreſces in the ſame manner, and for the ſame

657 Analyzed by Mr Bergman

reaſon, as the maſs left after boiling tobacco-pipe clay in oil of vitriol mentioned by Dr Lewis. Mr Bergman, who examined this ore, found, that 100 pounds of it contained eight of pure alum, beſides four of pure clay; and that the remainder was ſiliceous. This proportion, however, muſt be very variable, according to the quantity of rain which falls upon the ore.

658 Aluminous ores in Haſſia, Bohemia, and Scania.

A variety of aluminous ores are to be met with in different parts of the world. In Haſſia and Bohemia this ſalt is obtained from wood impregnated with bitumen. At Helſingborg in Scania, a turf is found conſiſting of the roots of vegetables mixed with nuts, ſtraw, and leaves, often covered with a thin pyritous cuticle, which, when elixated, yields alum: Even the ſulphu-

659 Alum, ſulphur, and vitriol extracted from the ſame ore.

reous pyrites is generally mixed with an argillaceous matter, which may be ſeparated by menſtrua. In ſome places, ſulphur, vitriol, and alum are extracted from the ſame material. The ſulphur riſes by diſtillation; the reſiduum is expoſed to the air till it effloreſces, after which a green vitriol is obtained by lixi-

660 Alum ſlate found at York in England.

viation, and alum from the ſame liquor, after no more vitriol will cryſtallize. The *alum ſlate*, from which ſalt is made near York in England, contains a conſiderable quantity of ſulphur; and therefore produces alum on the principles already mentioned.

661 Bergman's directions for the preparation of alum.

Mr Bergman has given very particular directions for the preparation of this ſalt from its ores, and minutely deſcribes the ſeveral operations which they muſt undergo. Theſe are.

662 Uſe of roaſting the ore.

1. Roasting. This is abſolutely neceſſary in order to deſtroy the pyrites; for on this the formation of the alum entirely depends; as the ſulphur of the pyrites will not part with its phlogiſton without a burning heat in the open air. By long expoſure to the air, indeed, the ſame effect will follow; but unleſs the ore be of a particular kind, and looſe in texture, ſo that the air can freely pervade it, the proceſs we ſpeak of cannot take place. The hard ores, therefore, cannot be

663 Expoſure to the air has ſometimes the ſame effect.

treated in this manner; and the earthy ores are not only unfit for ſpontaneous calcination, but for roaſting alſo, as they will not allow the air to pervade them and extinguiſh the fire. Such as are capable of ſpontaneous calcination, ſhould be ſupplied with ſome quantity

664 Earthy ores unfit for both operations.

of water, and laid on a hard clay bottom, as directed for making green vitriol. The roaſting is performed in Sweden in the following manner. Small pieces of the ore are ſtrewed upon a layer of burning ſticks to the thickneſs of half a foot. When the ſticks are

665 Method of roaſting the ore in Sweden.

conſumed, theſe are covered, nearly to the ſame thickneſs, with pieces burned before and four times lixiviated: Thus ſtrata are alternately laid of ſuch a thickneſs, and at ſuch intervals of time, that the fire may continue, and the whole maſs grow hot and ſmoke, but not break out into flame. The upper ſtrata may ſometimes be increaſed to a double thickneſs on account of the long continuance of the fire. When eight ſtrata are laid, another row is placed contiguous to the former; when this is finiſhed, a third; and ſo on until the heap be of a proper ſize, which rarely requires more than three rows. When the ore is once roaſted, it ſtill contains ſo much phlogiſton that water

666 How often the operation is to be repeated.

acts but little upon it; but after the operation is two or three times repeated, the ore yields its principles more freely: the roaſting may even be repeated to advantage till the whole be reduced to powder. The bitumen keeps up the fire; for which reaſon alternate layers of the crude ore are uſed; and in rainy weather theſe layers of unburnt ore ſhould be thicker. An heap, 20 feet broad at the baſe, two feet at the top, and conſiſting of 26 rows, is finiſhed in three weeks, but requires two or three months to be well burned, and three weeks to cool. The greater pyritous nuclei explode like bombs. In this proceſs the ſulphur of the pyrites is ſlowly conſumed, and the phlogiſticated acid penetrating the maſs, is fixed; after which the re-

667 Danger of raiſing the heat too much.

maining phlogiſton is gradually diſſipated. The chief art conſiſts in moderating the heat in ſuch a manner as to avoid with ſafety the two extremes; for too ſmall a fire would not be capable of forming the ſalt, while a heat too ſtrong would deſtroy it by melting the ore. The ſcoria are inſoluble in water, and therefore thrown away as uſeleſs. They are produced by violent winds, or by a ſtrong heat too much cloſed up; for it is neceſſary to make holes in the red ſtrata, that the fire may reach the back ſtratum which is to be laid on.

668 Rinman's method of burning the ore at Garphyttan.

Another method of burning was invented by the celebrated Rinman, and is practiſed at a place called *Garphyttan* in Sweden. There the ore itſelf is ſet on fire; and after burning is boiled, and yields alum in the ſame manner as the former. The heaps are formed in the following manner: Firſt the ſchiſt, burning from the furnace, is laid to the depth of four feet; if the fire be ſlow, then wood is added; after that a thin ſtratum of elixated ſchiſt; the third conſiſts of ſchiſt not burned; and the fourth of elixated ſchiſt a foot and a half thick; after that the burning ſchiſt, and ſo on. This method, however, is attended with ſome inconveniences. The vitriolic acid is partly diſſipated by the fire, and thus

Vitriolic acid and its combinations.

the quantity of alum is diminished: so much schist also is requisite in this method that it cannot all be elixated; and thus the heap must be perpetually increasing.

669 Method of burning the hard ores at Tolfa in Italy.

The hard ores containing bitumen, such as those of Tolfa, are burned upon wood for some hours like limestone, until they become pervious to water, and effloresce. The fire is extinguished as soon as the flame becomes white, and the smell of sulphureous acid begins to be perceived. When the ore cools, those particles which were nearest to the fire are placed outermost, and those which had been outermost within, the fire being again lighted. The ore is sufficiently burned when it can be broken with the hands. It is then heaped up near certain trenches, and watered five times a-day, particularly when the sun shines clear; the operation being destroyed by a continued rain and cloudy sky. In some places the ore is first burned and afterwards elixated; neither is there any way of knowing the proper methods of managing it but by experiment.

670 Method of elixating the burned ore at Garphyttan with cold water.

2. Elixation. This is performed in some places with hot, and at others with cold, water. At Garphyttan in Sweden, where the latter method is chosen, the receptacles, in the year 1772, were of hewn stone, having their joints united by some cement capable of resisting the liquor. Every set consisted of four square receptacles disposed round a fifth, which was deeper than the rest. The first receptacle is filled with roasted schist, and the ore lies in water for 24 hours; the water is then drawn off by a pipe into the fifth; from thence into the second, containing schist not yet washed; from that in like manner, after 24 hours, through the fifth into the third, and so into the fourth. The lixivium is then conveyed to the fifth, and allowed to stand in it; and lastly is drawn off into a vessel appro-

671 Other methods.

priated for its reception.—In other places the water passes over the schist that has been washed three times for six hours; then that which has been twice washed, next what has been once washed, and lastly, the ore which has been newly roasted.

672 Singular circumstance by which the alum may be destroyed.

Those who superintend the alum manufactories are of opinion that the alum is destroyed by passing the water first over the newly burnt ore, and then over that which has been previously elixated.

673 Of the proper strength of the lixivium before boiling.

The lixivium, before boiling, ought to be as richly impregnated with alum as possible, in order to save fuel, though this is frequently neglected. In some places the taste is used as the only criterion; but in others the weight of water which fills a small glass bottle is divided into 64 equal parts, each of which is called in Sweden a *panning*; and the quantity by which the same bottle, full of lixivium, exceeds it when filled with water, is supposed to indicate the quantity of salt dissolved.—This method may undoubtedly be reckoned sufficiently accurate for work conducted on a large scale: and though Mr Bergman gives formulae by which the matter may be determined to a scrupulous exactness, it does not appear that such accuracy is either necessary or indeed practicable in works conducted in a great way.

Those who manage the alum manufactories assert, that the cold lixivium ought to be made no richer than when the weight of the bottle filled with lixivium exceeds it when filled with water by 4¼ pannings, which shows the water to be loaded with $\frac{1}{15}$ of its weight of alum. If the overplus amounts to six pannings, which indicates its containing $\frac{1}{11}$ of salt, crystals are then deposited.—Congelation is of no use to concentrate the aluminous lixivium; for water saturated with alum freezes almost as readily as pure water.

674 Construction of the evaporating vessel.

3. Boiling the ley for chrystallization. The ley being first brought from the pits through canals made for the purpose, is put into a leaden boiler, at the back of which is a reservoir, out of which the loss sustained by evaporation is constantly supplied, so that the surface of that in the boiler continues always nearly at the same height. Various signs are used by different manufacturers to know when the ley is properly evaporated: some determining the matter by the floating of a new laid egg; others by dropping a small quantity on a plate, and observing whether it crystallizes on cooling; and lastly, others weigh the lixivium in the bottle abovementioned.

675 Proper strength of the evaporated liquor.

The boiling is supposed to be finished if the increase of weight be equal to 10 pannings; that is, if the water be loaded with $\frac{1}{6.4}$ of its own weight. It might, however, take up above ⅓ of its weight, or nearly 27 pannings; but as it has to be depurated by standing quiet before the crystals are formed, the liquor must not be fully saturated with salt.

676 Of the first crystallization.

The lixivium, when sufficiently concentrated by evaporation, flows through proper channels into coolers, where it is allowed to rest for about an hour to free it from the grosser sediment; after which it is put into wooden or stone receptacles to crystallize. In eight or ten days the remaining liquor, commonly called *mother ley*, or *magistral water*, is let off into another vessel. A great number of crystals, generally small and impure, adhere to the bottom and sides of the vessel, which are afterwards collected and washed in cold water.

677 Depuration of the crystals.

When a sufficient quantity of the small crystals are collected, they must then be put into the boiler for depuration. They are now dissolved in as small a quantity of water as possible; after which the lixivium is poured into a great tub containing as much as the boiler itself. In 61 or 81 days the hoops of the tub are loosed, and the aluminous mass bound with an iron ring; and in 28 days more the residuum of the solution is let out through a hole, and collected in a trench; after which the saline mass, which at Garphyttan in Sweden amounts to 26 tons, is dried and sold as depurated alum. The boiler emptied for the first crystallization is next filled two-thirds full with the magistral lixivium; and as soon as the liquor arrives at the boiling point, the other third is filled with crude lixivium, with which the evaporation is also constantly supplied. A certain quantity of the aluminous impurities left by washing the salts of the first crystallization in water is then added, and the above described process repeated. Only the first boiling in the spring is performed with the crude lixivium alone, the rest are all done as just now related.

678 Bergman's remarks on the proper form of the coolers.

—Mr Bergman remarks, that the time required for crystallization may undoubtedly be shortened. The reservoirs used in Sweden for this purpose (he says), are deep and narrow at the top; on which account they are not only long

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long in cooling, but the evaporation, which is abſolutely neceſſary for the cryſtallization, goes on very ſlowly, excepting in extremely warm weather, at the ſame time that the doors and windows are diſpoſed in ſuch a manner as to direct a current of air along the ſurface. In Italy he tells us that conical reſervoirs are uſed with the wide part uppermoſt.

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Alum cannot be formed by merely evaporating and cooling the ley, on account of the exceſs of acid.

It is remarkable, that pure alum cannot be obtained in very conſiderable quantity by merely evaporating and cooling the ley. The reaſon of this is, that the lixivium ſometimes acquires ſuch a conſiſtence, that it both cryſtallizes with difficulty, and produces impure cryſtals. The cauſe was unknown till the time of Mr Bergman, who has ſhown that it proceeds from an exceſs of vitriolic acid. Hence alſo we may ſee the reaſon why alkaline ſalts, volatile alkali in its pure ſtate, or even putrefied urine, when added to this

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This exceſs cannot be removed by mineral alkali, though it may be by vegetable and volatile alkalies, and beſt of all by pure clay.

thick ſolution, produce good cryſtals of alum when they cannot be obtained otherwiſe. It is remarkable that this impediment to cryſtallization is not removed by mineral alkali, though it is ſo by the vegetable and volatile alkalies, which is a phenomenon hitherto unexplained. According to our author, however, an addition of pure clay, to abſorb the ſuperabundant acid, is preferable to any other; and indeed it is reaſonable to think ſo, as the union of vitriolic acid and pure clay forms the ſalt deſired, which is not the caſe with any of the alkalies. To aſcertain this, he made the following experiments.

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Experiment ſhowing that an exceſs of vitriolic acid impedes the cryſtallization of alum.

1. He diſſolved 215 grains of pure alum in diſtilled water, in a ſmall cucurbit, and evaporated it over the fire till the ſurface of the liquor ſtood at two marks, which indicated, in a former evaporation, that it was fit for cryſtallization. 2. Having poured out this into a proper glaſs veſſel, he diſſolved other 215 grains, and added to the ſolution 24¼ grains of concentrated vitriolic acid. 3. This ſolution being likewiſe poured out, the experiment was repeated a third time, with the addition of 53 grains of vitriolic acid; and the glaſſes being at laſt ſet in a proper place for cryſtallization, the firſt yielded 155¾, the ſecond 130, and the third 100¼ grains of alum.

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Experiment to determine the uſefulneſs of adding clay to the ley.

This ſhows that an exceſs of vitriolic acid impedes the cryſtallization of the alum; but to determine how far this could be remedied by the addition of clay, farther experiments were neceſſary. Having therefore employed a magiſtral reſiduum, in which the exceſs of acid was nearly in the proportion already related, he added two drachms of clay in fine powder to a kanne, or Swediſh cantharus, of the liquor: he boiled the mixture for ten minutes; and on ſeparating the clay that remained, he found that 25¼ grains were diſſolved, which indicates an increaſe of 141 grains of alum. On gently boiling the liquor for half an hour, 75 grains of the clay were diſſolved, which indicated an increaſe of 416 grains of alum.

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Advantages of uſing clay rather than alkalies.

The addition of clay muſt therefore be much preferable to that of alkaline ſalts, not only as the former produces a conſiderable increaſe of alum, but alſo as there is no danger of adding too much; for we have already ſhown, that when the liquor is entirely deprived of its ſuperabundant acid, the neutralized clay is inſoluble in water. The earth itſelf, however, diſſolves ſo ſlowly, that there is not the leaſt danger of the acid being overſaturated by ſimply boiling them together.

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Alum generally contaminated by dephlogiſticated vitriol.

Alum, as commonly made, though depurated by a ſecond cryſtallization, yet is almoſt always found contaminated by dephlogiſticated vitriol; whence it grows yellow, and depoſits an ochre in ſolution when old. This is equally uſeful in ſome arts with the pureſt kind, and is even ſo in dyeing where dark colours are required; but where the more lively colours are wanted, every thing vitriolic muſt be avoided. This is done by the addition of pure clay, which precipitates the iron, and produces an alum entirely void of any noxious

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This defect remedied by the addition of pure clay.

or heterogeneous matter. Nor is this contrary to the laws of chemical attraction; for though iron is diſſolved by a ſolution of alum, and the earthy baſe of alum precipitated, and though in a ſolution of vitriol and alum the white earth falls firſt on an addition of alkali, and then the ochre; this happens only in conſequence of employing phlogiſticated or metallic iron, or ſuch as is but very little dephlogiſticated; for if the inflammable principle be any further diminiſhed, the attraction is thereby ſo much weakened, that the clay has a greater attraction for the vitriolic acid than the iron. The truth of this may be proved in many different ways. Thus, let a portion of alum be diſſolved in a ſolution of highly dephlogiſticated vitriol, and an alkali then added, the ochre of the vitriol will be firſt depoſited and then the clay: and provided there be a ſufficient quantity of the latter, the iron will all be precipitated; and hence we ſee that an aluminous ſolution mixed only with one of dephlogiſticated vitriol may readily be freed from it

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Perfect vitriol cannot be deſtroyed by clay.

But a ſolution of alum containing perfect vitriol cannot be freed from it effectually either by clay or alkali; for the former effects no decompoſition, and the latter, although it can deſtroy the vitriol, will undoubtedly decompoſe the alum in the firſt place. As long, therefore, as the ſolution is rich in alum, in may be employed in the common manner; but when the vitriolic ſalt begins to predominate, it muſt either be cryſtallized in its proper form, or be deſtroyed in ſuch a manner as to produce alum, which

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How the phlogiſton may be abſtracted from the vitriol.

may be accompliſhed in the following manner. Let the lixivium be reduced to a tenacious maſs with clay, and formed into cakes, which muſt be expoſed in an houſe to the open air. Thus the phlogiſton, which is powerfully attracted by the dephlogiſticated part of the atmoſphere, by degrees ſeparates from the iron, while the clay is taken up by its ſuperior attraction for the acid. The calcination is accelerated by fire; but it muſt be cautiouſly employed, leſt the acid ſhould be expelled.

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Epſom ſalt may be produced from the mother liquor.

In the alum manufactories in Sweden, a conſiderable quantity of vitriolated magneſia, or Epſom ſalt, is mixed with the alum. Mr Bergman directs this to be ſeparated by means of an uncalcined calcareous earth, which entirely deſtroys both the alum and vitriol; falling down to the bottom with the acid in form of a ſelenitic matter. This muſt be added to the boiling liquor gradually, leſt the effervеſcence ſhould cauſe the maſs to ſwell and run over the top of the veſſel. A juſt proportion deſtroys both the aluminous and vitriolic ſalt, on being properly agitated and heated; neither is there any danger of the Epſom

ſalt

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falt being decompofed in this procefs, the uncalcined earth being unable to feparate the magnefia from the acid. Were this method followed in the Swedifh manufactories, he is of opinion, that as much Epfom falt might be produced from them as would fupply the confumpt of that kingdom.

689 Superfluous acid might be advantageoufly diftilled.

With regard to the quantity of fuperfluous acid found in the magiftral lixivium, Mr Bergman informs us, that it amounted to five ounces in one kanne; fo that in a fingle boiler there is nearly 250 lb. But vitriol, when well dephlogifticated, retains its acid fo loofely that it may eafily be feparated by fire. He has no doubt, therefore, that if the furface of fuch a lixivium were firft increafed in order to let the phlogifton evaporate, the liquor might afterwards be advantageoufly committed to diftillation for the fake of its acid.

From what has been above delivered the neceffity will be fufficiently apparent of not continuing the coction even with pure clay to perfect faturation of the liquor: and this is further confirmed by M. Beaumé, who relates, that having boiled four ounces of earth of alum with two ounces of the falt, in a fufficient quantity of water, the acid became faturated to fuch a degree with earth, that the liquor loft its aluminous tafte entirely, and affumed that of hard fpring water. After filtration and evaporation, only a few micaceous cryftals, very difficult of folution, were formed by letting the liquor ftand for fome months.—Dr Sieffert informs us, that by boiling half an ounce of alum with half a drachm of flaked lime, cubical cryftals of alum may be obtained.

690 Epfom falt.

V. *With Magnefia.* The earthy fubftance called *magnefia alba* is never found by itfelf, and confequently this combination cannot originally take place by art. The vitriolic acid, however, is found combined with magnefia in great plenty in the bitter liquor which remains after the cryftallization of common falt; from whence the magnefia is procured by precipitating with a fixed alkali. If this liquor, which, when the common falt is extracted, appears like clean oil of vitriol, is fet by for fome time in a leaden veffel, a large quantity of falt fhoots, very much refembling Glauber's fal mirabile. This falt is in many places fold inftead of the true Glauber's falt; and is preferred to it, becaufe the true fal mirabile calcines in dry air, which the fpurious kind does not. If after the firft cryftallization of the bittern, the remainder is gently evaporated farther, a frefh quantity of Glauber's falt will fhoot; and if the liquor is then haftily evaporated, a falt will ftill be cryftallized; but inftead of large regular cryftals, it will concrete into very fmall ones, having fomething of the appearance of fnow when taken out of the liquid. Thefe falts are effentially the fame, and are all ufed in medicine as purgatives. The falt fhot into fmall cryftals is termed *Epfom falt,* from its being firft produced from the purging waters at Epfom in England. The bittern affording this kind of falt in fuch great plenty, thefe waters were foon neglected, as they yielded it but very fparingly, and the quantity prepared from them was infufficient for the demand. Neumann fays, that having infpiffated 100 quarts of Epfom-water, he fcarce obtained half an ounce of faline matter.—According to Mr Scheele's experiments, if a folution of Epfom and common falt be mixed together, a double decompofition enfues, and the mixture contains Glauber's falt and a combination of magnefia with marine acid. From this lixivium the Glauber's falt may be cryftallized in winter, but not in fummer; a great degree of cold being neceffary for this purpofe. From twelve pounds of Epfom falt and fix of common falt, Mr Scheele obtained, in a temperature three degrees below the freezing point, fix pounds of Glauber falt; but in a degree of cold confiderably greater, the produce was feven pounds and three quarters.

691 With filver.

VI. *With Silver.* Oil of vitriol boiled on half its weight of filver-filings, corrodes them into a faline mafs. This fubftance is not ufed in medicine nor in the arts. The only remarkable property of it is, that it has a very ftrong attraction for mercury; coagulating and hardening as much quickfilver as the acid weighed at firft. If the hard concrete be diluted with frefh acid, it melts eafily in the fire, and does not part with the mercury in the greateft heat that glafs veffels can fuftain. The vitriolic acid, by itfelf, ftrongly retains mercury, but not near fo much as when combined with filver.

Silver thus corroded by the vitriolic acid, or precipitated by it from the nitrous, may in great part be diffolved, by cautioufly applying a very little water at a time; and more effectually by boiling in frefh oil of vitriol.

692 Copper.

VII. *With Copper.* With this metal the vitriolic acid cannot be combined, unlefs in its concentrated ftate, and ftrongly heated. If pure oil of vitriol is boiled on copper filings, or fmall pieces of the metal, it diffolves it into a liquor of a deep blue colour, which eafily cryftallizes. The cryftals are of a beautiful blue colour, and are fold under the name of *blue vitriol,* or *Roman vitriol.*

693 Blue vitriol, how made.

Where fulphur is found in great plenty, however, Roman vitriol is made by ftratifying thin plates of copper with fulphur; and upon flowly burning the fulphur, its acid corrodes the copper. The metal is then to be boiled in water, that the faline part may be diffolved. The operation is to be repeated till all the copper is confumed; and all the faline liquors are to be evaporated together to the cryftallizing point. By this method, however, a great part of the acid is loft; and in Britain, where the fulphur muft be imported, we fhould think the pure acid preferable for thofe who prepare blue vitriol.

694 Phenomena on diftillation.

This falt, on being expofed to the fire, firft turns white, then of a yellowifh red colour. On urging it with a ftrong fire, the acid flowly exhales, and a dark red calx of copper remains. The whole of the vitriolic acid cannot be expelled from copper by heat: as much of it ftill remains as to render a part of the metal foluble in water. After this foluble part has been extracted, a little acid is ftill retained amounting to about $\frac{1}{12}$ of the calx.

695 Ufes.

Vitriol of copper is employed in medicine as a cauftic, in which refpect it is very ufeful; but when ufed internally, is dangerous, as indeed all the preparations of copper are found to be. It has, neverthelefs, according

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cording to Neumann, been recommended in all kinds of intermittents, and the lepra. The smallest portion, he says, occasions a sickness and nausea; a somewhat larger, reaching and violent vomitings, accompanied often with convulsions. If the quantity taken has been considerable, and is not soon discharged by vomiting, the stomach and intestines are corroded, intense pains, inflammations, and death, succeed.

696 Iron.

VIII. *With Iron.* The vitriolic acid does not act upon this metal till considerably diluted. Common oil of vitriol requires to be mixed with ten or twelve times its quantity of water before it will act briskly on the metal. In this state it effervesces violently with iron filings, or small bits of the metal, and a great quantity of inflammable vapour is discharged (see AIR). The liquor assumes a fine green colour; and by evaporation and slow coolings, very beautiful rhomboidal crystals are formed. These are named *salt of steel*, and are used in medicine; but for the salt made of the pure acid and iron, the common copperas, made with the impure acid extracted from pyrites, is commonly substituted. This is generally esteemed a venial fraud, and no doubt is so in medicinal respects; but when it is considered, that, by this substitution, common copperas is imposed on the ignorant, at the price of 2 *s per* pound, the affair appears in a different light.

697 Salt of Steel

698 Precipitation of iron from the vitriolic acid.

Pure vitriol of iron is originally of a much more beautiful appearance than common copperas, and retains its colour much better; the reason of which is, that the salt thus prepared has more phlogiston than the copperas. If either of the kinds, however, are exposed to the air for a sufficient length of time, part of the acid is dissipated, and the vitriol becomes yellowish or brownish. If the salt is now dissolved in water, a brown precipitate falls, which is part of the iron in a calcined state. If the liquor is separated from this precipitate by filtration, a similar one forms in a short time, and by long standing a considerable quantity subsides. According to Dr Lewis, the precipitation is greatly expedited by a boiling heat; by which more of the metal separates in a few minutes than by standing without heat for a twelvemonth. This change takes place in no other metallic solutions.

699 Yellow for house painting.

The calx of iron, precipitated by quicklime from green vitriol, appears, when dry of a yellow colour; and it is recommended in the Swedish transactions, instead of yellow ochre, as a colour for house-painting.

700 Preservative for wood.

Solutions of green vitriol are also recommended for preserving wood, particularly the wheels of carriages, from decay. When all the pieces are fit for being joined together, they are directed to be boiled in a solution of vitriol for three or four hours; and then kept in a warm place for some days to dry. By this preparation, it is said, wood becomes so hard, that moisture cannot penetrate it; and that iron nails are not so apt to rust in this vitriolated wood as might be expected, but last as long as the wood itself.

701. Tin.

IX. *With Tin.* This metal cannot be dissolved in the vitriolic acid, but in the same manner as silver; namely, by boiling concentrated oil of vitriol to dryness upon filings of the metal. The saline mass may then be dissolved in water, and the solution will crystallize. The salt, however, formed by this union, is not applied to any useful purpose. A salt of tin, indeed, formed by the union of vitriolic acid with this metal, has been recommended for some medical purposes, and processes are given for it in the dispensatories; but they have never come much into practice.

702 Lead.

X. *With Lead.* While lead is in its metallic state, the vitriolic acid acts very little upon it, either in a diluted or concentrated state; but if the metal is dissolved in any other acid, and oil of vitriol added, a precipitation immediately ensues, which is occasioned by the combination of vitriolic acid with the lead. This precipitate will be more or less white as the metal is more or less deprived of its phlogiston by calcination before solution. If a little strong spirit of nitre is poured upon *litharge*, which is lead calcined to the greatest degree possible without vitrification, the acid unites itself to the metal with considerable effervescence and heat. Some water being now poured on, and the phial containing the mixture shaken, a turbid solution of the litharge is made. If a little oil of vitriol is then added, it throws down a beautifully white precipitate; and the acid of nitre, being left at liberty to act upon the remaining part of the litharge, begins anew to dissolve it with effervescence. When it is again saturated, more oil of vitriol is to be dropped in, and a white precipitate is again thrown down. If any of the litharge is still undissolved, the nitrous acid, being set at liberty a second time, attacks it as at first; and by continuing to add oil of vitriol, the whole of the litharge may be converted into a most beautiful and durable white. Unfortunately this colour cannot be used in oil, though in water it seems superior to any. If the process is well managed, an ounce of spirit of nitre may be made to convert several pounds of litharge into a white of this kind.

703 A beautiful white colour.

704 Quicksilver.

XI. *With Quicksilver.* The dissolution of quicksilver in vitriolic acid cannot be performed but by a concentrated oil and strong boiling heat. The metal is first corroded into a white calx, which may afterwards be easily dissolved by an addition of fresh acid. Every time it is dissolved, the mercury becomes more and more fixed and more difficult to dry. If the exsiccation and dissolution has been repeated several times, the matter becomes at last so fixed as to bear a degree of red heat. This combination is the basis of a medicine formerly of some repute, under the name of *turbith mineral*. The process for making turbith mineral is given by the author of the Chemical Dictionary as follows.

705 Turbith mineral.

"Some mercury is poured into a glass retort, and upon it an equal quantity of concentrated oil of vitriol, or more, according to the strength of the acid. These matters are to be distilled together, in the heat of a sand-bath, till nothing remains in the retort but a dry saline mass, which is a combination of the vitriolic acid and mercury. The acid which passes into the receiver is very suffocating and sulphureous; which qualities it receives from the phlogiston of the mercury. The white saline mass which is left at the bottom of the retort is to be put into a large vessel; and upon it are to be poured large quantities of hot water at several different times. The water weakens the acid, and takes it from the mercury; which is then precipitated towards the bottom of the vessel, in form of a very shining yellow powder. The water with

Vitriolic acid and its combinations. which it is waſhed contains the acid that was united with the mercury, and likewiſe a little mercury rendered ſoluble by means of the very large quantity of acid

Moſt chemiſts have believed, that a portion of vitriolic acid remains united with the turbith mineral, only too little to render it ſoluble in water. But Mr Beaumé, having examined this matter, affirms, that turbith mineral contains no acid, when it has been ſufficiently waſhed; and that, by frequently boiling this preparation in a large quantity of diſtilled water, not a veſtige of acid will adhere to it."

706 Dr Lewis's directions. Dr Lewis, who is of opinion that the whole of this mercurial calx is ſoluble in a very large quantity of water, deſires the water with which it is waſhed to be impregnated with ſome alkaline ſalt; which makes the yield of turbith greater than when pure water is uſed. The author of the Chemical Dictionary alſo obſerves, that the precipitate remains white till well freed from the acid; and the more perfectly it is waſhed, the deeper yellow colour it acquires.

707 Zinc. XII. *With Zinc.* This ſemimetal is not acted upon by the vitriolic acid in its concentrated ſtate; but, when diluted, is diſſolved by it with effervеſcence, and with the extrication of an inflammable vapour in the ſame manner as iron. Neumann obſerves, that, during the diſſolution, a grey and blackiſh ſpongy matter fell to the bottom, but, on ſtanding for ſome days, was taken up, and diſſolved in the liquor, nothing being left but a little yellowiſh duſt ſcarcely worth mentioning. Six parts of oil of vitriol, diluted with an equal quantity of water, diſſolves one part of zinc.

708 White vitriol. The product of this combination is *white vitriol;* which is uſed in medicine as an ophthalmic, and in painting for making oil-colours dry quickly: what is uſed for this purpoſe, however, is not made in Britain, but comes from Germany. It is made at Goſlar by the following proceſs. An ore containing lead and ſilver, having been previouſly roaſted for the obtaining of ſuphur (ſee Metallurgy), is lixiviated with water, and afterwards evaporated in leaden boilers, as for the preparation of green vitriol: but here a regular cryſtallization is prevented; for when the ſalt has aſſumed any kind of cryſtalline form, theſe cryſtals are made to undergo the watery fuſion in copper caldrons. It is then kept conſtantly ſtirring till a conſiderable part of the moiſture is evaporated, and the matter has acquired the conſiſtence of fine ſugar. White vitriol generally contains ſome ferruginous matter, from which it may be entirely freed by ſome freſh zinc; for this ſemimetal precipitates from the vitriolic acid all other metallic ſubſtances; but notwithſtanding this ſtrong attraction, the vitriolic acid is more eaſily expelled by diſtillation from white than green or blue vitriol. Towards the end of the diſtillation of white vitriol, the acid ariſes exceedingly concentrated, though ſulphureous: ſo that, if mixed with common oil of vitriol, it will heat it almoſt as much as oil of vitriol heats water.

709 Regulus of antimony. XIII. *With Regulus of Antimony.* To combine vitriolic acid with regulus of antimony, the ſame method muſt be uſed as directed for uniting it with quickſilver, for making turbith mineral, *viz.* to employ a very concentrated acid, and to diſtil in cloſe veſſels. The ſame phenomena alſo occur in this caſe as in making turbith mineral; a very ſuffocating ſulphureous acid ariſes; and as Mr Geoffroy obſerves, a true ſulphur ſublimes into the neck of the retort; a white, ſaline, tumefied, maſs remains in the veſſel; and when the veſſels are unluted, a white fume iſſues, as in the ſmoking ſpirit of libavius. See *Combinations of marine acid with tin, infra.* Vitriolic acid and its combinations.

710 Regulus of cobalt. XIV. *With Regulus of Cobalt.* From a combination of the vitriolic acid with cobalt, a red ſalt may be obtained. To procure it, one part of cobalt, reduced to a very fine powder, may be mixed with two or three of concentrated acid, diluting the liquor after it has been digeſted for 24 hours, and then filtering and evaporating it.

711 Arſenic. XV. *With arſenic.* Neumann relates, that powdered white arſenic being diſtilled in a retort with oil of vitriol, a tranſparent ſublimate like glaſs aroſe, which in a few days loſt its tranſparency, and became opaque like the arſenic itſelf. The arſenic remaining in the retort ſuſtained an open fire without any ſenſible alteration. The author of the Chemical Dictionary ſays, that if a concentrated vitriolic acid is diſtilled from arſenic, the acid which comes over ſmells exactly like marine acid. When the ſolution is diſtilled till no more acid ariſes, the retort is then almoſt red-hot, and no arſenic is ſublimed; but remains fuſed at the bottom of the retort; and, when cold, is found to be an heavy, compact maſs, brittle and tranſparent as cryſtal-glaſs. This kind of arſenical glaſs, expoſed to the air, ſoon loſes its tranſparency from the moiſture it attracts, which diſſolves and partly deliquiates it. This deliquium is extremely acid—By digeſting one part of arſenic with two of concentrated oil of vitriol, diluting the ſolution with water, and then filtering and evaporating, we obtain a yellowiſh ſalt which ſhoots into pyramidal, tranſparent, and ſhining cryſtals. None of the three laſt mentioned combinations have been found applicable to any uſeful purpoſe.

712 Oil. XVI. *With Oil.* The product of this combination is a thick black ſubſtance, very much reſembling balſam of ſulphur in colour and conſiſtence; to which it is ſometimes ſubſtituted. If this ſubſtance is diſtilled with a gentle heat, great part of the acid becomes volatile, and evaporates in white fumes, having a pungent ſmell reſembling that of burning ſulphur. This goes by the name of *volatile* or *ſulphureous vitriolic acid*; and a ſalt was formerly prepared from it by ſaturation with fixed alkali, which was thought to poſſeſs great virtues. From its inventor it was called the *ſulphureous ſalt of Stahl.* The moſt ſingular property of this volatile acid is, that though the vitriolic in its fixed ſtate is capable of expelling any other acid from its baſis, the volatile one is expelled by every acid, even that of vinegar. It is very difficultly condenſible, as we have already taken notice; and, when mixed with water, ſeems ſcarcely at all acid, but rather to have a bitteriſh taſte. 713 Volatile ſulphureous acid.

Several methods have been propoſed for procuring this acid from burning ſulphur, which yields it in its greateſt degree of volatility, as well as concentration; but the produce is ſo exceedingly ſmall, that none of them are worth mentioning. Dr Prieſtley has given very good directions for obtaining the volatile vitriolic acid in the form of air. His method was, to pour, on ſome 714 How procured by Dr Prieſtley.

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ſome oil of vitriol contained in a phial, a very ſmall quantity of oil olive; as much as was ſufficient to cover it. He then applied the proper apparatus for the reception of air in quickſilver (ſee Air); and, holding a candle to the phial, the volatile vitriolic acid ruſhed out in great quantity. Had he received this air in water, inſtead of quickſilver, the conſequence would have been, that ſome part of it, at leaſt, would have been abſorbed by the water, and a ſulphureous acid liquor produced. This ſeems indeed almoſt the only method of procuring the ſulphureous vitriolic acid of any tolerable ſtrength; but it is never required in the form of a liquor, except for experimental purpoſes. The only uſeful property hitherto diſcovered about this kind of acid is, that it is remarkably deſtructive of colours of all kinds; and hence the fumes of ſulphur are employed to whiten wool, &c.

715 Charcoal.

XVII. *With Phlogiſton of charcoal.* If charcoal is mixed with concentrated vitriolic acid, and the mixture diſtilled, the ſame kind of acid is at firſt obtained, which comes over when oil is uſed; and towards the end, when the matter begins to grow dry, a true ſulphur ſublimes. The beſt way, however, of producing ſulphur from the vitriolic acid is by combining it, when in a perfectly dry ſtate, with the phlogiſton. By this means ſulphur may very readily be made at any time. The proceſs is generally directed to be performed in the following manner.

716 Sulphur prepared from vitriolated tartar.

Reduce to fine powder any quantity of vitriolated tartar. Mingle it carefully with a 16th part of its weight of charcoal-duſt. Put the whole into a covered crucible ſet in a melting furnace. Give a heat ſufficient to melt the ſalt; and when thoroughly melted, pour it out on a flat ſtone. The vitriolated tartar and charcoal will now be converted into a ſulphureous maſs, ſimilar to a combination of alkaline ſalts with ſulphur. See *Alkaline Salts*, below.

717 Spirit of wine.

XVIII. *With Spirit of wine.* The reſult of this combination is one of the moſt extraordinary phenomena in chemiſtry; being that fluid, which, for its extreme degree of volatility, was firſt diſtinguiſhed by the name of *ether*: and now, ſince a liquor of the like kind is diſcovered to be preparable from ſpirit of wine by means of other acids, this ſpecies is diſtinguiſhed by the name of *vitriolic ether*. The method of preparing this ſubtle liquor recommended by M. Beaumé, ſeems to be the beſt of any hitherto diſcovered.

718 Ether.

Mix together equal parts by weight, of highly rectified ſpirit of wine and concentrated oil of vitriol, or ſomewhat more than two meaſures of ſpirit of wine with one of the acid. The mixture is to be made in a flint glaſs retort, the bottom and ſides of which are very thin, that it may not break from the heat which is ſuddenly generated by the union of theſe two ſubſtances. The ſpirit of wine is firſt put into the retort, and then the acid is poured in by a glaſs-funnel, ſo that the ſtream may be directed againſt the ſide of the glaſs; in which caſe it will not exert much of its force on the ſpirit, but will lie quietly below at the bottom. The retort is now to be very gently ſhaken, that the acid may mingle with it by little and little. When the mixture is completed, very little more heat will be neceſſary to make the liquor boil.

This mixture is to be diſtilled with as briſk and quick a heat as poſſible; for which reaſon, immediately after the acid and ſpirit are mixed, the retort ſhould be put into a ſand furnace heated as much as the mixture is. The diſtillation ſhould be continued only till about one-third of the liquor is come over; if it is continued farther, part of the vitriolic acid riſes in a ſulphureous ſtate. In the retort a thick, black, acid matter remains, which is ſimilar to a combination of oil of vitriol with any inflammable matter, and from which a little ſulphur may be obtained. Along with the ſulphureous acid, a greeniſh oil, called *oleum vitrioli dulcis*, ariſes, which has a ſmell compounded of that of the ether and ſulphureous acid: and Mr Beaumé has ſhown that it is compounded of theſe two; for if it is rectified with an alkali, to attract the acid, it is changed into ether. If, after the diſtillation of the ether, ſome water be poured into the retort, the liquor by diſtillation may be brought back to the ſtate of a pure vitriolic acid.

As the ſteams of the ethereal liquor are exceedingly volatile, and at the ſame time a quick fire is neceſſary to the ſucceſs of the operation, the receiver muſt be carefully kept cool with very cold water or with ſnow. Care muſt alſo be taken to prevent any of the ſulphureous acid ſteams from coming over; but as it is impoſſible to prevent this totally, the liquor requires rectification. This is the more neceſſary, as a part of the ſpirit of wine always riſes unchanged. From this acid the liquor is eaſily ſet free, by adding a ſmall quantity of alkaline ſalt, and re-diſtilling with a very gentle heat; but as ſpirit of wine is likewiſe very volatile, the diſtillation muſt be performed in a very tall glaſs. Dr Black recommends a matraſs, or bolt-head, with a tin-pipe adapted to the head, ſo as to convey the ſteams at a right angle, to be condenſed in the receiver. When this fluid is to be prepared in great quantities, the ether, by proper management, may be made to equal half the weight of the ſpirit of wine employed. Mr Dollfuſs has made many important experiments on this ſubject; of which the following is an abſtract: 1. Two pounds of vitriolic acid were mixed with as much of ſpirit of wine, and the mixture diſtilled with a very gentle fire. The firſt ten ounces that came over conſiſted of a liquor ſtrongly impregnated with ether, and of an agreeable odour. This was put by itſelf and marked A. It was followed by a ſtronger ethereal liquor, of which a ſmall quantity only would mix with water. Of this there were 12 ounces, which were alſo put by themſelves, and marked B. By continuing the proceſs two ounces more were obtained, which ſmelled of ſulphur, and were marked C. The diſtillation was now continued with a view to concentrate the vitriolic acid, when three drachms of a thicker kind of ether were found ſwimming on a weak ſulphureous acid. This thick liquid was not in the leaſt volatile, and in conſiſtence reſembled an expreſſed oil. 2. Twenty-four ounces of ſpirit of wine were now added to the reſiduum of the former diſtillation, and the proceſs recommenced. The firſt ſeven ounces that came over were poured to the dulcified ſpirit marked A. Next paſſed over ten ounces of a tolerably pure ether, which was mixed with the contents of B; beſides two ounces that had a ſulphureous ſmell, which were mixed with C. By a repeated dephlegmation of what remained in the retort were obtained five ounces of a weak ſulphureous acid; and

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the remainder being again mixed with 20 ounces of ſpirit of wine, yielded firſt ſix ounces of the liquor marked A; then four ounces of pure ether put into that marked B; and after that another ounce marked C. By continuing the diſtillation four ounces of weak ſulphureous acid were obtained, on which floated a little oil of wine. 3. The remainder, which was very thick, and covered with a ſlight pellicle, was mixed with 20 ounces of ſpirit of wine, and yielded five ounces of dulcified ſpirit marked A; eight ounces of pure ether marked B; and at laſt one ounce of the ſame, which had rather a ſulphureous ſmell. This was followed by a few drops of acid; but the remainder frothed up with ſuch violence, that an end was put to the operation, in order to prevent its paſſing over into the receiver.

By theſe four diſtillations there were obtained from ſix pounds of ſpirit of wine and two of oil of vitriol, 28 ounces of dulcified ſpirit of vitriol and 38 of ether; which laſt, when rectified by diſtillation over manganeſe, yielded 28 ounces of the beſt ether. At the end of this diſtillation were produced 13 ounces of weak acetous acid; and the liquor of the laſt running marked C, afforded, by rectification, four ounces of good ether. The ſulphureous acid liquor yielded four ounces of weak acetous acid, and three drachms of naphtha reſembling a diſtilled oil in conſiſtence.

By theſe proceſſes the vitriolic acid was rendered quite thick and black; its weight being reduced to 24 ounces. The blackneſs was found to be owing to a powder which floated in the liquid, and could neither be ſeparated by ſubſiding to the bottom nor riſing to the top. The liquor was therefore diluted with eight ounces of water, and filtered through powdered glaſs; by which means the black ſubſtance was collected, partly in powder, and partly in grains of different ſizes. It felt very ſoft between the fingers, and left a ſtain upon paper like Indian ink; but though waſhed with 24 ounces of water, ſtill taſted acid. Half an ounce of it diſtilled in a retort yielded a drachm and an half of weak acetous mixed with a little ſulphureous acid; the reſiduum was a black coal, which by calcination in an open fire for a quarter of an hour, yielded 25 grains of white aſhes, conſiſting of ſelenite, calcareous earth, and magneſia. A drachm of it digeſted with nitrous acid, which was afterwards diſtilled from it, and then diluted with diſtilled water and filtered, yielded a few cryſtals, which appeared to be genuine ſalt of tartar, an inſoluble ſelenite being left behind. On rectifying the vitriolic acid freed from the black matter and diluted with eight ounces of water, nine ounces of ſulphureous acid were firſt obtained, after which followed an ounce of acid rather high-coloured, and then the vitriolic acid quite colourleſs. It now weighed only $19\frac{1}{4}$ ounces, and its ſpecific gravity was but 1.723, while that of the acid originally employed had been 1.989.

On repeating the proceſs with ſix pounds of ſpirit of wine to two of oil of vitriol, the firſt 12 ounces that came over were ſpirit of wine almoſt totally unchanged; then two ounces ſmelling a little of ether; and afterwards two pounds, of which about one-third were ether. When about five pounds had been drawn off, the diſtilling liquor began to ſmell ſulphureous; and after nine ounces more had been drawn off, the frothing up of the matter in the retort obliged him to put an end to the operation. The acid was then filtered through pounded glaſs as before, and afterwards committed to diſtillation. The three firſt ounces were a weak ſulphureous acid; then followed an ounce more concentrated, and of a red colour; then another of a yellowiſh caſt; after which the reſt of the acid came over quite colourleſs. The whole weighed 27 ounces, and the ſpecific gravity of it compared with diſtilled water was as 1.667 to 1.000.

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719 Properties of ether.

Ether is the lighteſt of all known fluids, except air; and is ſo volatile, that *in vacuo* its boiling point is 20° below 0° of Fahrenheit's thermometer. If a ſmall quantity is poured out on the ground, it inſtantly evaporates, diffuſing its fragrance all through the room, and ſcarce perceptibly moiſtening the place on which it fell. It difficultly mixes with water, as being of an oily nature: ten parts of water, however, will take up one part of ether. Its great volatility renders it ſerviceable in nervous diſeaſes, and removing pains, when rubbed on with the hand, and kept from evaporating immediately. By ſpontaneous evaporation, it produces a great degree of cold. (See EVAPORATION and CONGELATION). The moſt extraordinary property, however, is, that if gold is diſſolved in aqua-regia) ſee *Metallic Subſtances*, below), and ether added to the ſolution, the gold will leave the acid and permanently unite with the ether. The exceeding great volatility of ether renders it very eaſily inflammable even on the approach of flame; and therefore it ought never to be diſtilled, or even poured from one veſſel to another, by candle-light. If a leſs quantity of the vitriolic acid is added to the ſpirit of wine than what is ſufficient to produce ether, the product is called *ſpiritus vitrioli dulcis*. The following experiment made by Wallerius, induced him and others to think, that the vitriolic acid was convertible into the nitrous.

720 Experiment in favour of the tranſmutation of vitriolic into nitrous acid.

"Some ſalt of tartar (ſays he) being mixed with the dulcified ſpirit of vitriol, or perhaps with the ether (for the author expreſſes himſelf a little ambiguouſly), the full bottle ſtopt with a cork, tied over with bladder, and laid on its ſide; on ſtanding for four months, the greateſt part of the ſpirit was found to have eſcaped, and the ſalt was ſhot into hexangular priſmatic cryſtals reſembling nitre. It taſted ſtrongly of the ſpirit, but had no other particular taſte. Laid on a burning coal, it crackled, exploded with a bright flaſh, and flew into the air. He afterwards found, that by adding to the ſpirit a drop or two of any acid, the ſalt cryſtallizes the ſooner; that in this caſe it has a ſouriſh taſte, but in other reſpects is the ſame with that made without acid. This ſalt-petre (ſays the author) promiſes, from the violence of its exploſion, to make the ſtrongeſt gun-powder in the world, but a very dear one. Though the experiment ſhould not be applicable to any uſe in this way, it will probably contribute to illuſtrate the generation of nitre: as it palpably ſhows nitre, that is, the acid or characteriſtic part of nitre, produced from the vitriolic acid and phlogiſton.

721 Not concluſive.

We cannot here help again regretting that chemiſts of ſuperior abilities ſhould ſometimes leave very important diſcoveries only half finiſhed, ſo that chemiſts of an inferior rank know not what to make of them. Had Wallerius,

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Wallerius, who seems more than once to have been in possession of this salt, only poured on it a few drops of oil of vitriol, the peculiar colour and smell of its fumes must have been a much more convincing proof of the reality of the transmutation than that of mere deflagration; because the latter can be otherwise accounted for.

722

Violent explosions from the application of heat.

It is certain, that many sustances, water itself not excepted, will explode with great violence if suddenly heated beyond what they are able to bear. If spirit of wine is confined in a close vessel, it will also by means of heat burst it as effectually as water; and as the vapours of this substance are inflammable, the explosion will be attended with a flash if any flame is near. In like manner ether, on the approach of a candle, takes fire, and goes off in a flash like lightning; but this happens, not from any thing nitrous, but from its great volatility and inflammability. If therefore the vapours of the ethereal liquors are confined, and heat is applied suddenly to the containing vessel, their great volatility will cause them make an instantaneous effort against the sides of it, which increasing with a swiftness far beyond that of aqueous or spirituous vapours, will make a much quicker as well as a much stronger explosion than either of them; and if a flaming substance is near, the explosion will be attended with a bright flash like that of the ether itself.

In the experiment now before us, the salt tasted strongly of the spirit, or ether, from which it was made. The spirit was therefore confined in the crystals of salt; and this volatile liquor, which, even under the pressure of the atmosphere, boils with the heat of 100° of Fahrenheit, was, in a confined state, subjected to the heat of a burning coal; that is, to more than ten times the degree of heat necessary to convert it into vapour. The consequence of this could be no other, than that the particles of salt, or perhaps the air itself, not being capable of giving way soon enough to the forcible expansion of the ether, a violent explosion would happpen, and the salt be thrown about; which accordingly came to pass, and might very reasonably be expected, without any thing nitrous contained in the salt.

2d 722

Cavallo's method of purifying ether.

Mr Cavallo describes an easy and expeditious method of purifying ether, though a very expensive one; as out of a pound of the common kind scarce three or four ounces will remain of that which is purified. The method of purifying it, he says, was communicated to him by Mr Winch chemist in London, and is to be performed in the following manner. "Fill about a quarter of a strong bottle with common ether, and pour upon it twice as much water; then stop the bottle and give it a shake, so as to mix the ether for some time with the water. This done, keep the bottle for some time without motion, and the mouth of it downwards, till the ether be separated from the water, and swims above it; which it will do in three or four minutes. Then opening the bottle with the mouth still inverted, let the greatest part of the water run out very gently; after this, turn the bottle with the mouth upwards; pour more water upon the ether, shaking and separating the water as before. Repeat this operation three or four times; after which the ether will be exceedingly pure, and capable of dissolving elastic gum, though it could not do so before."

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As great part of the ether undoubtedly remains mixed with the water after this process, our author remarks, that it might be worth while to put the water into a retort and distil the ether from it, which will come sufficiently pure for common use. He observes also, that "it is commonly believed that water combines with the purest part of the ether when the two fluids are kept together; though the contrary seems to be established by this process. According to Mr Wastrumb, we may obtain from the residuum of vitriolic ether a resin containing vitriolic acid, vinegar, Glauber's salt, selenite, calcareous earth, silex, iron, and phosphoric acid.

§ 2. *Of the* Nitrous *Acid and its Combinations.*

This acid is far from being so plentiful as the vitriolic. It has been thought to exist in the air; and the experiments of Mr Cavendish have shown, that it may be artificially composed, by taking the electric spark in a mixture of dephlogisticated and phlogisticated air. See Aerology, n° 77.

724

Of the preparation of nitre.

With regard to the preparation of nitre, Dr Black observes, that it is made in great plenty in the more southern parts of Europe; likewise in the southern parts of Persia, in China, the East Indies, and in North America. We have had no accounts of the manner in which it is prepared in the East Indies, no person on the spot having taken particular notice of the manufacture. The general account is, that it is obtained from the soil of certain districts which are called *saltpetre grounds*; where the soil is very cold, barren, and unhealthy. The salt is there ready formed by nature. It is only necessary to gather large quantities of the earth, and to put it into a cavity through which a great quantity of water is poured, which dissolves the nitre; and the lixivium runs into an adjacent pit, out of which it is lifted in order to be evaporated and obtained in the form of crystals. This account, however, has been thought unsatisfactory; because there is hardly any part of Europe in which it is found in this manner. 725

725

Discovered in some places in Podolia in Poland;

It is discovered indeed in some very large districts in Poland, particularly in Podolia, where the country is flat and fertile, and had been once very populous, but is now in a great measure deserted. It is there obtained from tumuli or hillocks, which are the remains of former habitations; but these are the only places in which it is found in any considerable quantity.

726

In Spain and America.

In Spain, it is said that the inhabitants extract it from the soil after a crop of corn. It has been found in America in lime-stone grounds, in the floors of pigeon-houses, tobacco-houses, or the ruins of old stables, where a number of putrefying vegetables were once collected. In general, however, it is extracted from artificial compounds or accidental mixtures, where animal and vegetable substances have been fully putrefied by being exposed to the air with any spongy or loose earth, especially of the calcareous kind, and open to the north or north-east wind, and more or less covered from the heat or rains.

727

Requisites for its formation.

This last particular is absolutely necessary to its formation in any quantity; for the heat, by evaporating the moisture too much, prevents it from being produced, and the rains wash it away after it is already made.

728

Cramer's artificial compost for making nitre.

Cramer, an author of the greatest credit, informs us in his Docimastics, that he made a little hut exposed to the fresh air of the country,

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country, with windows to admit the winds. In this he put a mixture of garden mold, the rubbifh of lime, and putrid animal and vegetable fubftances. This he frequently moiftened with urine; and in a month or two found his compofition very rich in nitre, yielding at leaft one-eight part of its weight.

729 How prepared in Hanover.

It is manufactured in Europe by making artificial compounds with lefs trouble. In Hanover it is got by collecting the rakings of the ftreets; which are built up into mud-walls that are allowed to remain a certain time, when the furface is found covered with a white faline efflorefcence. A perfon is employed to fcrape this off; and putting it into a veffel, it is wafhed with water to diffolve the nitre, and the remaining earthy matter is again plaftered on the mud-walls, and frefh matter brought from the ftreets to renew them occafionally: and by this fimple method a confiderable quantity is obtained.

730 In other parts of Germany.

In Germany the peafants are directed by law to build mud-walls of this kind with the dung and urine of animals, and fome ftraw. After they have ftood for fome time, and the vegetable and animal fubftances are rotten, they afford a confiderable quantity of nitre.

731 In France.

In France it is obtained from accidental collections of this kind; as where loofe earth has been long expofed to the contact of animal fubftances, as the ruins of old ftables, pigeon-houfes, &c. Sometimes from the mould upon the ground where dunghills have been lying. A particular fet of people go about in fearch of thefe materials; and when, by making a fmall effay, they find that they will turn to account, they put the materials into a large tub with a perforated bottom, and another which is water-proof put below it. Some ftraw is interpofed betwixt the two; and on pouring water upon the materials, it foaks through them, undergoes a kind of filtration in paffing through the ftraw, and is then drawn off by a cock placed in the the under-tub, and boiled to a proper confiftence for cryftallization. The cryftals are at firft brown and very impure, but by repeated diffolution and cryftallization become pure and white.

732 Dr Black's conclufions concerning the nature of falt-petre.

From thefe particulars relating to the hiftory of falt-petre, Dr Black concludes, that it is not properly a foffil, being produced at the furface of the ground. Margraaf difcovered a fmall quantity of it in the analyfis of fome of the waters about Berlin, and others have found it in the wells about fome great cities: but no true nitre has ever been found in fprings; fo that this nitrous falt may be fuppofed to have derived its origin from the quantity of putrid matters with which all cities abound. All rich and fertile foils are found to contain it; and in the hot countries, where the products of nature are numerous, and putrefaction carried on very faft, they are often very rich in nitre. This may happen in fome places from the conflux of waters; which remaining for fome time on the furface, and afterwards exhaling, left the faline particles behind.

733 Suppofed to be the laft effect of putrefaction.

On the whole, Dr Black concludes, that neither nitre nor its acid does exift in the air, becaufe it might eafily be detected there; though many have embraced this opinion from its being ufually found at the furface of the ground. He is of opinion, that it is the effect of the laft ftage of putrefaction of animal and vegetable fubftances; and it is never to be found except where thefe or their effluvia are prefent, and never till the putrefaction is complete. It has been a matter of difpute, whether it exifted in thofe matters before the procefs of putrefaction, or was produced by it. But it is pretty certain, fays the Doctor, that it originated in them; for the fun-flower, tobacco, and other plants, are found to contain it before putrefaction: and fome have even afferted, that plants placed in the earth, deprived of all its faline fubftances, will yield it. The compofitions recommended by Cramer are the fitteft for producing a complete degree of putrefaction, provided they contain a moderate degree of humidity, and that the quantity expofed to the air be defended from too great a heat by the fun, which would dry up its moifture; and likewife from too great a degree of cold, which likewife checks fermentation. The importance of the calcareous earth in fuch a compofition would likewife favour the conclufions juft now drawn; for the moft remarkable effect of this earth is to promote and perfect the putrefaction of thefe fubftances. It would feem, therefore, that the true fecret of the production of nitre is to mix properly together animal and vegetable fubftances with earth, particularly of the calcareous kind; expofing them to the air with a moderate degree of humidity, fufficient to promote their putrefaction in the moft effectual manner; and when the putrefaction is carried to the utmoft height, we may then expect that nitre will be produced.

734 Diftinguifhing characteriftic of the nitrous acid.

The diftinguifhing characteriftic of the nitrous acid is its great difpofition to unite with the phlogifton; and, when fo united, firft to become exceedingly volatile, and at laft to be diffipated in a very white bright flame: this is called its *detonation* or *deflagration*. In the ftrongeft ftate in which this acid is procurable in a liquid form, it is of a reddifh yellow colour, and continually exhales in denfe, red, and very noxious fumes; and in this ftate is called *fmoking*, or, from its inventor, *Glauber's*, fpirit of nitre.

I. To extract the Nitrous Acid by means of the *Vitriolic.*

735 Spirit of nitre.

Into a glafs retort put two pounds of good falt-petre, and pour upon it 18 ounces of concentrated oil of vitriol; fet the retort in a fand-heat, and lute on a large receiver with the compofition already recommended, for refifting acid fumes; the mixture will grow very warm, and the retort and receiver will be filled with red vapours. A fmall fire is then to be kindled, and cautioufly raifed till no more drops will fall from the nofe of the retort. What comes over will be a very ftrong and fmoking fpirit of nitre.

736 Rectification.

In this procefs, the nitrous acid is generally mixed with part of the vitriolic which comes over along with it, and from which it muft be freed if defigned for nice purpofes. This is moft effectually done by diffolving in it a fmall quantity of nitre, and rediftilling the mixture. The vitriolic acid which came over in the firft diftillation is kept back by the nitre in the fecond, combining with its alkaline bafis, and expelling a proportionable quantity of the nitrous acid.

737 Different methods of diftilling.

We have here directed the pure vitriolic acid to be ufed, in order to expel the nitrous one; but for this purpofe any combination of the vitriolic acid with a metallic or earthy bafis may be ufed, though not with equal advantage. If calcined vitriol is made ufe of,

Nitrous acid and its combinations.

as much phlogiston is communicated by the calx of iron contained in that salt as makes the nitrous acid exceedingly volatile, so that great part of it is lost. If calcined alum, or selenite, is made use of, the vitriolic acid in these substances immediately leaves the earth with which it was combined, in order to unite with the alkaline basis of the nitre, and expels its acid: but the moment the nitrous acid is expelled from the alkali, it combines with the earth which the vitriolic acid had left; from which it cannot be driven without a violent fire; and part of it remains obstinately fixed, so as not to be expelled by any degree of heat. Hence the produce of spirit, when nitre is distilled with such substances, always turns out considerably less than when the pure vitriolic acid is used. Alum is preferable to selenite, for the purposes of distilling spirit of nitre; because the acid does not adhere so strongly to argillaceous as to calcareous earth.

According to Weigleb, the nitrous acid may be expelled not only by clay, gypsum, and other substances containing the vitriolic acid, but even by various kinds of vitrifiable earth. Clean pebbles, quartz in the form of sand, pieces of broken china and stone ware, powdered glass, *&c* mixed with nitre in the proportion of six to one, always expel the acid, though imperfectly. In France the acid is always extracted by means of clay.

The reason of these decompositions is, that the alkaline basis of the nitre attracts the siliceous earth, whose fixedness in a vehement fire gives it an advantage over the volatile nitrous acid, in the same manner that the weak acid of phosphorus or arsenic will also expel it by reason of their fixedness in the fire.

Even spirit of salt, according to Margraaff's experiments, may be used for distilling the spirit of nitre. That celebrated chemist informs us, that on distilling nitre with eight or nine times its quantity of strong marine acid, a spirit comes over which consists chiefly of the nitrous acid, but has also some portion of that of sea salt. The reason of this is shown in Mr Kirwant's experiments on chemical attractions*. In the present case, however, the decomposition may be facilitated by the strong attraction of the nitrous acid for phlogiston; for it is well known, that on mixing the nitrous and marine acids together, the latter is always dephlogisticated. It seems therefore that in this case a double decomposition takes place, the nitrous acid uniting itself to the phlogiston of the marine, and the latter attaching itself to the alkali of the nitre.

* See n° 292.

738 Uses.

Spirit of nitre is very useful in the arts of dyeing and refining, where it is known by the name of *aquafortis*; and therefore an easy and cheap method of procuring it is a valuable piece of knowledge. Many difficulties, however, occur in this process, as well as that for the vitriolic acid. Oil of vitriol, indeed, always expels the nitrous acid with certainty; and on distilling the mixture, a spirit of nitre arises; but if a glass retort is used for the purpose of distilling this acid, the quantity of residuum left in distillation is so great, and so insoluble in water, being no other than vitriolated tartar, that the retort must always be broken in order to get it out; and the produce of spirit will scarce afford the breaking a retort. If earthen retorts are made use of, they must certainly be of that kind called stone-ware, and the price of them will be very little if at all inferior to that of glass. Iron pots are said to be made use of in the distillation of common aquafortis in large quantities; but they have the great inconvenience of making a quantity of the acid so volatile, that it not only will not condense, but spreads its suffocating vapours all round in such a manner as to prove very dangerous to those who are near it. If an iron vessel, therefore, is thought of for the purpose of distilling aquafortis, it will be proper at least to attempt luting over the inside with a mixture of gypseous earth and sand, to prevent as much as possible the acid from attracting the metal.

Dephlogisticated spirit of nitre is obtained by distilling the smoking kind with a gentle heat, until what remains is as colourless as water. It is distinguished by emitting white and not red fumes like the other kind, when set in a warm place. It must be kept constantly in the dark, otherwise it will again become phlogisticated, and emit red vapours by the action of the light; the same thing will also take place if it be heated with too violent a fire.

II. To procure the Nitrous Acid by means of *Arsenic.*

739 Blue aquafortis.

Pulverise equal quantities of dried nitre and white cryftalline arsenic; mix them well together, and distil in a glass-retort with a fire very cautiously applied; for the arsenic acts on the nitre with such a violence, and the fumes are here so volatile, that unless great care is taken, a most dangerous explosion will almost certainly happen. As, in this case, the nitrous fumes arise in a perfectly dry state, some water must be put into the receiver, with which they may unite and condense. The aquafortis so produced will have a blue colour, owing to the inflammable principle separated from the arsenic, by which its extreme volatility is likewise occasioned. If this blue aquafortis is exposed to the air, its colour soon flies off. If instead of the white arsenic we employ the pure arsenic acid, the distilled liquor will have no blue colour.

Nitrous Acid COMBINED,

740 Salt-petre.

I. *With Vegetable fixed Alkali.* This salt, combined with the nitrous acid to the point of saturation, regenerates nitre. It is observable, however, according to Neumann, that there is always some dissimilarity between the original and regenerated nitre, unless quicklime is added. The regenerated salt, he says, always corrodes tin, which the original nitre does not; owing probably to a quantity of phlogisticated acid remaining in it. Boiling with quicklime deprives it of this quality, and makes it exactly the same with original nitre.

741 Cubic-nitre.

II. *With Fossile alkali.* The neutral salt arising from a combination of the nitrous acid and fossile alkali is somewhat different from common nitre; being more difficult to crystallize, inclining to deliquate in the air, and shooting into crystals of a cubical form, whence it gets the name of *cubic nitre*. Its qualities are found somewhat inferior to the common nitre; and therfore it is never made, unless by accident, or for experiments.

742 Fusibility.

Nitre is one of the most fusible salts. It is liquefied in a heat much less than what is necessary to make it red; and thus remain in tranquil fusion, without swelling. If nitre thus melted be left to cool and fix, whe-

Nitrous acid and its combinations. whether it has been made red-hot or not in the fusion, it coagulates into a white, semi-transparent, solid mass, called *mineral crystal*, having all the properties of nitre itself. By this fusion, Mr Beaumé observes that nitre loses very little, if any, of the water contained in its crystals, since the weight of mineral crystal is nearly the same with that of the nitre employed.

When nitre is kept in fusion with a moderate heat, and at the same time does not touch any inflammable matter, nor even flame, it remains in that state without suffering any very sensible alteration; but if it is long kept in fusion with a strong fire, part of the acid is destroyed by the phlogiston which penetrates the crucible; and hence the nitre becomes more and more alkaline.

743 Uses. Nitre is of very extensive use in different arts; being the principal ingredient in gun-powder; and serving as an excellent flux to other matters; whence its use in glass making. (See GLASS.) It is also possessed of a considerable antiseptic power; whence its use in preserving meat, to which it communicates a red colour. In medicine, nitre is used as a diuretic, sedative, and cooler; but very often sits uneasy on the stomach. The resemblance of the crystals of nitre to those of Glauber's salt has sometimes been the occasion of dangerous mistakes. Dr Alexander mentions a swelling over the whole body of a woman, occasioned by her taking a solution of nitre instead of Glauber's salt. Two mistakes of the same kind we have also known. In one an ounce, and in the other upwards of two ounces, of nitre were swallowed. The symptoms occasioned were universal coldness and shivering, extreme debility and sickness at stomach, cold sweats and faintings. Neither of the cases proved mortal. The cure was effected by cordials and corroborants.

744 Sal prunella. A process has obtained a place in the dispensatories for a supposed purification of nitre by means of flower of brimstone. A pound of salt-petre is to be melted in a crucible, or small iron vessel; and an ounce of flowers of sulphur thrown upon it, by small quantities at a time: a violent deflagration ensues on each addition; and after the whole is put in, the salt is poured out in moulds, and then called *sal prunella*. It has been disputed whether the nitre was at all depurated by this process; Dr Lewis thinks it is not. From our own experience, however, we can affirm, that by this means a sediment falls to the bottom, which carries with it any impurities that may have been in the nitre, and leaves the fluid salt clear and transparent as water. This precipitate is probably no other than a vitriolated tartar formed by the union of the sulphureous acid and alkali of the nitre, which being less fusible than the nitre, subsides in a solid form and clarifies it.

745 Nitrous ammoniac. III. *With Volatile Alkali.* The nitrous acid seems peculiarly adapted to an union with volatile alkali; saturating as much, or rather more of it than the strongest vitriolic acid is capable of doing. The product is a very beautiful salt, called *volatile nitre*, or *nitrous sal ammoniac*. It very readily dissolves, not only in water, but in spirit of wine, which distinguishes it from the vitriolic and common kind of sal ammoniac. It also requires less heat for its sublimation: indeed care must be taken not to apply too great a heat for this purpose, as the nitrous sal ammoniac has the property of deflagrating by itself without any addition of inflammable matter; and this it does more or less readily, as the volatile alkali with which it was made was more or less impure and oily.

746 Dr Ward's white drop. The medical virtues of this kind of nitre have not been inquired into. It seems to have made the principal ingredient in the famous Dr Ward's white drop, which was celebrated as an antiscorbutic; with what justice those who have tried it must determine.

747 Calcareous nitre. IV. *With Calcareous Earths.* These the nitrous acid dissolves into a transparent colourless liquor; but for this purpose it must be very much diluted, or the solution will have a gelatinous consistence. This compound is not applicable to any useful purpose. It has a very acrid taste; and, if inspissated, attracts moisture from the air. If it is totally dried, it then resembles an earthy matter, which deflagrates very weakly. By distillation in a retort, almost all the acid may be expelled, and what little remains flies off in an open fire.

748 Nitrous acid decomposed. Mr Pott, who has particularly examined the combination of nitrous acid with quicklime, says that the acid suffered remarkable alterations by distillation from quicklime, and repeated cohobations upon it. By these experiments he obtained a salt more sensibly susceptible of crystallization and detonation, than what can be obtained by a single combination. From his experiments it would seem, that nitrous acid, by this treatment with quicklime, was capable of being entirely decomposed.

If a solution of chalk in the nitrous acid be evaporated to dryness, and then gently calcined, it acquires the property of shining in the dark, after having been exposed to the sun's rays, or even to the light of a candle. This substance, from its inventor, is called 749 Phosphorus. *Baldwin's phosphorus*; or, from its being necessary to keep it in a glass hermetically sealed, *phosphorus hermeticus*. (See EARTHS).

V. *With Argillaceous Earths and Magnesia.* All that is known concerning the combinations of nitrous acid with these earths is, that the first produce astringent, and the second purgative compounds, similar to alum and Epsom salt, and which are not susceptible of crystallization.

750 Gold. VI. *With Gold.*—Till very lately it has been the opinion of chemists, that the nitrous acid by itself was incapable of acting upon this metal.—Dr Brandt, however, produced before the Swedish academy of sciences, a solution of gold in the nitrous acid, obtained in parting, by that acid, a mixture of gold and silver.—The mixed metal was boiled with aquafortis in a glass body fitted with a head and receiver, the liquor poured off, and the coction repeated with fresh parcels of stronger and stronger nitrous spirit, till all the silver was judged to be extracted. The last parcel was boiled down till the matter at the bottom looked like a dry salt; on boiling this in fresh aquafortis in close vessels, as before, a part of the gold was dissolved, and the liquor tinged yellow. But though gold is by this means truly soluble in the nitrous acid, the union is extremely slight; the gold being not only precipitated on the addition of silver, but likewise spontaneously on exposure to the air.—Dr Lewis very justly observes, that this solution may have been often made

unknown

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unknown to the chemiſt who did ſo; and probably occaſioned the miſtakes which ſome have fallen into, who thought that they were in poſſeſſion of aquafortis capable of tranſmuting ſilver into gold. Notwithſtanding theſe authorities, Mr Kirwan is of opinion that the nitrous acid is in no caſe able to diſſolve gold; the metal being only intimately mixed or diffuſed through it.

751 Silver.

II. *With Silver.*—Pure ſpirit of nitre will diſſolve its own weight of ſilver; and ſhoots with it into fine white cryſtals of a triangular form, conſiſting of very thin plates joined cloſely one upon another. Theſe cryſtals are ſomewhat deliqueſcent; of an extremely bitter, pungent, and nauſeous taſte; and, if taken internally, are highly corroſive and poiſonous. They melt in a

752 Lunar cauſtic.

ſmall heat, and form, on cooling, a dark-coloured maſs ſtill more corroſive, called *lunar cauſtic*, or *lapis infernalis*. They readily diſſolve in water; and, by the aſſiſtance of warmth, in ſpirit of wine. In the *Acta Naturæ Curioſorum*, tom. vi. there is a remarkable hiſtory of ſilver being volatilized by its combination with the nitrous acid. Four ounces of ſilver being diſſolved in aquafortis, and the ſolution ſet to diſtil in an earthen retort, a white tranſparent butter roſe into the neck, and nothing remaining behind; by degrees the butter liquefied, and paſſed down into the phlegm in the receiver. The whole being now poured back into the retort, the ſilver aroſe again along with the acid. The volatilization being attributed to the liquor having ſtood in a laboratory where charcoal was bringing in, the experiment was repeated with a freſh ſolution of ſilver, and a little powdered charcoal, with the ſame event.

753 Colours produced by ſolution of ſilver.

Solution of ſilver in the nitrous acid ſtains hair, bones, and other ſolid parts of animals, and different kinds of wood, of all the intermediate ſhades from a light brown to a deep and laſting black. The liquors commonly ſold for ſtaining hair brown or black, are no other than ſolutions of ſilver in aquafortis, ſo far diluted in water as not ſenſibly to corrode the hair.

It gives a permanent ſtain likewiſe to ſundry ſtones; not only to thoſe of the ſofter kind, as marble, but to ſome of conſiderable hardneſs, as agates and jaſpers. The ſolution for this purpoſe ſhould be fully ſaturated with the metal; and the ſtone, after the liquor has been applied, expoſed for ſome time to the ſun. M. du Fay obſerves (in a paper on this ſubject in the French memoirs for 1728), that if the ſolution be repeatedly applied, it will penetrate into the whitiſh agate, or chalcedony, about one-twelfth of an inch: that the tincture does not prove uniform, on account of the veins in the ſtone: that the colours, thus communicated by art, are readily diſtinguiſhed from the natural, by diſappearing on laying the ſtone for a night in aquafortis: that, on expoſing it to the ſun afterwards for ſome days, the colour returns: that the ſolution gave ſomewhat different tinctures to different ſtones; to oriental agate, a deeper black than to the common chalcedony; to an agate ſpotted with yellow, a purple; to the jade ſtone, a pale browniſh; to the common emerald, an opaque black; to common granite, a violet unequally deep; to ſerpentine ſtone, an olive; to marble, a reddiſh, which changed to purple, and fixed in a brown; that on ſlates, talcs, and amianthus, it had no effect.

If a ſolution of ſilver be diluted with pure water, a conſiderable quantity of pure mercury added, and the whole ſet by in a cold place; there will form by degrees a precipitation and cryſtallization reſembling a little tree, with its root, trunk and branches, called *arbor Dianæ*, or the *philoſophic ſilver tree*. Another kind of artificial vegetation may be produced by ſpreading a few drops of ſolution of ſilver upon a glaſs plate, and placing in the middle a ſmall bit of any of the metals that precipitate ſilver, particularly iron. The ſilver quickly concretes into curious ramifications all over the plate.

754 Arbor Dianæ.

755 Solution of ſilver decompoſed.

Like other metallic ſolutions, this combination of the nitrous acid with ſilver is decompoſed by fixed and volatile alkalies, calcareous earths, and ſeveral metals, (ſee the *Table* of *Affinities*); but with ſeveral peculiar circumſtances attending the precipitation. With metals, the ſilver is readily and copiouſly thrown down at firſt, but ſlowly and difficultly towards the end. The menſtruum generally retains ſome portion of the ſilver, as the ſilver almoſt always does of the metal which precipitated it. For recovering the ſilver from aquafortis after parting, the refiners employ copper. The ſolution, diluted with water, is put into a copper veſſel, or into a glaſs one with thin plates of copper, and ſet into a gentle warmth. The ſilver begins immediately to ſeparate from the liquor in form of fine grey ſcales, or powder; a part of the copper being diſſolved in its place, ſo as to tinge the fluid more or leſs of a bluiſh green colour. The plates are now and then ſhaken, that ſuch part of the ſilver as is depoſited upon them may fall off, and ſettle to the bottom. The digeſtion is continued till a freſh bright plate, kept for ſome time in the warm liquor, is no longer obſerved to contract any powdery matter on the ſurface; when the liquor is poured off, and the precipitate waſhed with freſh parcels of boiling water. It is obſervable, that though the acid in this proceſs ſaturates itſelf with the copper, in proportion as it lets go the ſilver, yet the quantity of copper which it takes up is not near ſo great as that of ſilver which it depoſits. One drachm of copper will precipitate three of ſilver, and ſaturate all the acid that held the three drachms diſſolved.

756 Characters curiouſly marked on the inſide of a glaſs by means of the ſun's light.

Calcareous earths, as chalk or quicklime, throw down a part of the ſilver, but leave a very conſiderable part ſuſpended in the liquor. If the earth be moiſtened with the ſolution into the conſiſtence of a paſte, and expoſed to the ſun, it changes its white colour to a dark purpliſh black; diſtinct characters may be exhibited on the matter, by intercepting a part of the ſun's light by threads, ſlit paper, *&c.* placed on the outſide of the glaſs. Culinary fire does not affect its colour: after the maſs has been exſiccated by this, it changes as before, on expoſure to the ſun.

Mild volatile alkaline ſpirits, added to a ſolution of ſilver, precipitate but little, and cauſtic volatile alkalies none. Pure fixed alkalies, and alkalies rendered cauſtic by quicklime, throw down the whole. Fixed alkalies impregnated with inflammable matter by calcination with animal coals, occaſion at firſt a conſiderable precipitation; but if added to a larger quantity, take up a great part of the metal again. Mr Margraaf relates, that edulcorated calces of ſilver totally diſſolve, both in a lixivium of theſe alkalies and in vo-

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latile ſpirits; and that the marine acid precipitates the ſilver from the volatile, but not from the fixed, alkaline ſolution. Kunckel reports that the calx precipitated by volatile ſpirits made with quicklime, fulminates or explodes in the fire; and that by inſpiſſating a ſolution of pure ſilver, melting the dry reſiduum, pouring it on ſpirit of urine ſuperſaturated with ſalt, and ſetting the mixture in a gentle warmth, a blood-red maſs is produced, ſo tough as to admit of being wound about the fingers.

757 Copper. III. *With Copper*. The nitrous acid very readily diſſolves this metal into a green-coloured and very cauſtic liquor. The ſolution, if properly evaporated, will cryſtallize; but the cryſtals are deliqueſcent, and therefore difficult to be preſerved. The only uſe of this

758 Verditer. combination is for the preparation of the pigment called *verditer*. Of this there are two kinds, the blue and green. The blue is by far the brighteſt colour, and conſequently the moſt valuable. It has been ſaid that this is obtained by precipitating a ſolution of copper by any calcareous earth; and therefore is ſold by the refiners who have large quantities of ſolution of copper accidentally made. The ſolution is ſaid to be precipitated by chalk, or whiting; and that the precipitate is the beautiful blue colour called *verditer*. By this method, however, only the green kind can be obtained. The blue we have found to be of a quite different nature, and formed by precipitation with a gentle heat from a ſolution of copper in volatile alkali. See the article Colour-making.

759 Iron. IV. *With Iron*. On this metal the concentrated nitrous acid acts very violently, and plentifully corrodes, but does not diſſolve it; the calx falling almoſt as faſt as diſſolved; and when it is once let fall, freſh acid will not take it up again. If the acid was diluted at firſt, it takes up a conſiderable porportion, provided the metal be leiſurely added. If the ſolution is performed with extreme ſlowneſs, the colour will be green; but if otherwiſe, of a dark red. It does not cryſtallize; and, if inſpiſſated to dryneſs, deliquates in the air.

760 Tin. V. *With Tin*. Concentrated nitrous acid acts upon tin with great force, but only corrodes the metal into a white indiſſoluble maſs. In order to obtain a perfect ſolution of tin in the nitrous acid, the metal muſt be put in by very little at a time, and a diluted aquafortis made uſe of. This ſolution has been conſiderably uſed in dyeing, and is remarkable for heightening red colours of all kinds; but the ſolution made with *aqua-regis* is preferable.

761 Lead. VI. *With Lead*. Proof aquafortis, lowered with an equal quantity of water, diſſolves about half its weight of lead. On diluting the ſolution with a large quantity of water it turns milky, and depoſites great part of the metal. The ſolution ſhoots, upon exhaling part of the menſtruum, into ſmall pyramidal cryſtals with ſquare baſes, of an auſtere ſweet taſte.

762 Quickſilver ſuppoſed to be extracted from lead. In the memoirs of the French academy for 1733, there is a particular account of an experiment, in which mercury is ſaid to have been extracted from lead by diſſolving in it the nitrous acid. During the diſſolution, there fell a precipitate which is plainly proved to be mercury, and was looked upon to be one of the conſtituent parts of the lead ſeparated by this ſimple proceſs: it ſeems probable, however, that the mercury in this caſe had been contained in the aquafortis; for pure lead diſſolved in pure aquafortis gives no ſuch precipitate.

The cryſtals of lead in the nitrous acid, when thrown into the fire, do not deflagrate as other combinations of this acid with metallic or ſaline baſes; but crackle violently, and fly round, with great danger to the by-ſtanders. If they are rubbed into very fine powder, they may then be melted without any danger. By repeated diſſolutions in freſh aquafortis, they at laſt form a thick fluid like oil, which cannot be dried without great difficulty. This compoſition is not adapted to any particular uſe, and is a violent poiſon.

VII. *With Quickſilver*. Aquafortis of ſuch a degree of ſtrength as to take up half its weight of ſilver, diſſolves with eaſe above equal its weight of mercury into a limpid liquor, intenſely corroſive and poiſonous, which ſpontaneouſly ſhoots into white cryſtals. Theſe cryſtals, or the ſolution exſiccated, and moderately calcined, aſſume a ſparkling red colour; and are uſed in medicine as an eſcharotic, under the name of *red precipitate*. The precipitate has ſometimes been given internally, it is ſaid, in very large quantities; even a whole drachm at one doſe. But this would ſeem incredible; and the peſent practice does not countenance the taking of red precipitate inwardly. This ſolution ſeems to have been what gave the efficacy to Ward's white drop. 763 Quickſilver. 764 Red precipitate.

When red precipitate is prepared in quantity, it is proper to diſtil the mercurial ſolution; becauſe moſt of the aquafortis may then be ſaved. It is exceedingly pure, if by purity we mean its being free of any admixture of vitriolic or marine acid; but is conſiderably tainted with the inflammable principle of the mercury extricated during the diſſolution. In conſequence of this, it is very volatile and ſmoking; which has generally, though improperly, been taken as a ſign of ſtrength in the nitrous acid.

VIII. *With Biſmuth*. This ſemimetal is very readily acted upon by the nitrous acid. Proof aquafortis diſſolves about half its weight of biſmuth. If the metal was haſtily added, the ſolution proves of a greeniſh colour; if otherwiſe, it is colourleſs and tranſparent. Unleſs the acid was diluted with about an equal quantity of water, a part of the biſmuth cryſtallizes almoſt as faſt as it diſſolves. The metal is totally precipitated both by fixed and volatile alkalies. The laſt, added in greater quantities than are ſufficient for precipitation, take it up again. The liquor generally appears greeniſh; by alternate additions of the alkaline ſpirit and ſolution, it becomes bluiſh or purple. Fixed alkalies calcined with inflammable matter likewiſe diſſolve the biſmuth after they have precipitated it. 765 Biſmuth.

The only uſe of this compound is for the precipitate, which is uſed as a coſmetic, under the name of *magiſtery of biſmuth*. The common way of preparing this is by diluting the ſolution very largely with water, upon which it turns milky, and a fine white precipitate falls, which is to be well edulcorated with water, and is then employed as a coſmetic both in waſhes and pomatums. 766 Magiſtery of biſmuth.

Concerning the preparation of this coſmetic, Neumann obſerves, that there are ſundry variations.— "Some (ſays he) takes aqua-regia for the menſtruum; and for the precipitant a ſolution of ſea-ſalt, alkalies, ſpirit

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spirit of wine, &c. Some mix with the solution of bismuth a solution of benzoin in spirit of wine, and thus obtain a magistery compounded of bismuth and benzoin. Others add a solution of chalk to the metalline solution, and precipitate both together by alkalies. I have made trial with a good number of different precipitants; and found, that with common fixed alkali and caustic alkali, with watery and vinous alkaline spirits, the magistery was white, and in considerable quantity; the liquor, after the precipitation with volatile spirits, appearing blue. That oil of vitriol threw down a white precipitate very copiously: but that with spirit of salt, or spirit of vitriol, the precipitate was in very small quantity, in colour like the foregoing; distilled vinegar making no precipitation at all. Common rectified spirit of wine, and tartarized spirit, common water, and lime-water, gave white precipitates. Solutions of nitre, vitriolated tartar, sal mirabile, alum, borax, common salt, sal ammoniac, the combination of marine acid with calcareous earth, and terra foliata tartari, all precipitated the bismuth white. With a solution of gold in aqua-regia the magistery proved grey; with a solution of the same metal in aqua-regia made with spirit of salt, the precipitate was likewise grey, and in small quantity; with solution of copper in aquafortis, white, and in very small quantity, the liquor continuing blue; with solution of vitriol of copper, white; with solution of mercury sublimate, white and plentiful; with solution of iron in aquafortis, yellowish; with solution of lead in aquafortis, and of sugar of lead, white; with solution of zinc in aquafortis there was little precipitate; and with solutions of silver, tin, regulus of antimony, and of mercury, in the same acid, none at all."

767 Zinc.

IX. *With Zinc.* Upon this semimetal the nitrous acid acts with greater violence than any other, and will forsake any other metallic substance for it. The whole is very soon dissolved into a transparent colourless liquor. The calces of flowers of zinc are likewise soluble in the nitrous acid; but neither the solution of the flowers, nor of the metal itself, have been yet found applicable to any useful purpose. Neumann remarks, that on extracting with nitrous acid the soluble parts of calamine, which is an ore of zinc, the solution, inspissated to dryness, left a reddish brown mass, which on digestion with spirit of wine exploded and burst the vessel.

768 Regulus of antimony.

X. *With Regulus of Antimony.* The nitrous acid rather corrodes than dissolves this semimetal. The corroded powder forms a medicine formerly used under the name of *bezoar mineral*, but now disregarded.

769 Regulus of cobalt.

XI. *With Regulus of Cobalt.* This semimetal dissolves readily in the nitrous acid, both in its metallic form and when reduced to a calx. The solution is of a red colour. Hence the nitrous acid furnishes means of discovering this semimetal in ores after strong calcination; very few other calces being soluble in the nitrous acid, and those that are not influencing the colour.

770 Regulus of cobalt, how discovered in ores.

XII. *With Nickel.* This semimetal is easily dissolved by the nitrous acid into a deep green liquor; but neither this solution, nor indeed the semimetal of which it is made, has hitherto been found of any use.

XIII. *With Arsenic.* This substance is readily dissolved by the nitrous acid; which abstracts the phlogiston, and leaves the pure arsenical acid behind. See below *Acid of Arsenic.*

XIV. *With Expressed Oils.* These, as well as all other fatty or unctuous substances, are considerably thickened and hardened by their union with the nitrous acid. There is only one preparation where this combination is applied to any use. It is the *unguentum citrinum* of the shops. This is made by adding to some quantity of melted hog's-lard a solution of quicksilver in the nitrous acid. The acid, though in a diluted state, and combined with mercury, nevertheless acts with such force on the lard, as to render the ointment almost of the consistence of tallow.

771 Oils.

772 Unguentum citrinum.

773 Spirit of wine.

XV. *With Vinous Spirits.* If highly rectified spirit of wine and strong spirit of nitre are suddenly mixed together, the acid instantly becomes volatile, and is dissipated with great heat and effervescence in highly noxious red fumes. If the acid is cautiously poured into the spirit, in the proportion of five, six, or even ten parts of spirit to one of acid, and the mixture distilled in a glass retort set in a water-bath, an exceedingly fragrant and volatile spirit comes over, used in medicine as a diuretic and cooler, under the name of *spiritus nitri dulcis.* This liquor is not acid; nor has what remains in the retort any more the characteristics of nitrous acid, which seems to be entirely decomposed in this process. (See the following article.)

774 Spiritus nitri dulcis.

775 Nitrous ether.

With the nitrous acid and spirit of wine, may also be made an exceedingly volatile liquor, called *nitrous ether*, to distinguish it from the vitriolic abovementioned. The proportions of nitrous acid and spirit of wine to each other for nitrous ether, are two of the acid by weight to three of the spirit. Dr Black's process for making it is as follows. Take four ounces of strong phlogisticated nitrous acid; and having cooled it by putting it into a mixture of salt and snow, or into water cooled very near the freezing point, by putting pieces of ice into it, he puts it into a phial, and pours upon it an equal quantity of water, likewise cooled very low, in such a manner that the water may float as much as possible on the surface of the spirit. Six ounces of strong spirit of wine are then put in, so as to float in like manner on the surface of the water; the phial is placed in a vessel containing cold water: and so great is the power of cold in restraining the action of bodies, that if the mixture was too cold, no ether would be produced; but at the temperature just mentioned, the ether begins to be formed in a few hours, with some little effervescence, and an expulsion of a small quantity of nitrous air. We must provide for the escape of this elastic fluid, by having an hole in the cork, or the vessel would be broken. The whole of the ether will be formed in a few days, and may be separated from the rest of the liquor by means of a funnel, shaped as in Pl. CXXXIV. fig. 9.

776 Woulfe's process for procuring it in large quantities.

To procure the nitrous ether in large quantities, Mr Woulfe recommends the following process. Put into a retort four pounds of nitre, then mix together four pounds of vitriolic acid, and three pounds five ounces of spirit of wine. These are poured on the nitre by adding only two ounces at a time: the vitriolic acid acting on the nitre, produces a sufficient degree of heat; and the acid of the nitre uniting with the

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the ſpirit, forms a nitrous ether, which flies off from the mixture, and is condenſed in a number of veſſels placed in cold water.—To obtain good nitrous ether readily, and at one diſtillation, Mr Dollfuſs adviſes to diſtil four parts of nitre of mangaueſe, four of vitriolic acid, and eight parts of ſpirit of wine.

777 Inquiry into the nature of ether.

Macquer ſuppoſes that ether is the moſt oily part or quinteſſence of ſpirit of wine. But it cannot be proved that ether contains any oil. And, beſides, if this were the caſe, thoſe acids which have the ſtrongeſt attraction for water would produce the greateſt quantity of ether; which is found not to be the caſe: and it is moſt probable that ether is produced by a combination of ſome part of the acid with a portion, particularly the inflammable part, of the ſpirit of wine; and it has been ſhown by chemical experiments, that every kind of ether contains a part of the acid employed. Dr Black himſelf has formed ether without any ſpirit at all, by expoſing nitrous acid highly phlogiſticated for ſome months to the light of the ſun. This was owing to the attraction of the principle of inflammability; which it is well known that light has the power of affording to bodies that attract it with force.

Nitrous Acid DECOMPOSED,

778 Oils fired by ſpirit of nitre.

I. *By Eſſential Oils.* If equal quantities of ſtrong nitrous acid and oil of cloves are poured into the ſame veſſel, the mixture inſtantly takes fire; both acid and oil burning with great fury till only a light ſpongy coal remains. Dr Lewis obſerves, that this experiment does not always ſucceed, and that there are but few oils which can be fired with certainty, without attending to a particular circumſtance firſt diſcovered by M. Rouelle, and communicated in the French Memoirs for the year 1747. "On letting fall into the oil equal its quantity of acid, the mixture effervesces, ſwells, and a light fungous coal ariſes: a little more of the acid poured upon this coal ſets it inſtantly on fire. By this method almoſt all the diſtilled oils may be fired by ſpirit of nitre of moderate ſtrength. Expreſſed oils alſo may be ſet on fire by a mixture of the nitrous acid and oil of vitriol; the uſe of which laſt ſeems to be to abſorb the aqueous humidity of the ſpirit of nitre.

779 Nitre alkalized.

II. *By Charcoal.* By this ſubſtance the nitrous acid cannot be conveniently decompoſed, unleſs it is combined with an alkaline or metallic baſe. For the purpoſe of decompoſing the acid, common ſaltpetre is moſt convenient. The proportions recommended by Dr Lewis for alkaliſating nitre, are four ounces of the ſalt to five drachms of powdered charcoal. If theſe are carefully mixed, and injected by little and little into a tubulated retort made red hot, and fitted with a large receiver and a number of adopters, a violent deflagration will enſue on every addition, attended with a great quantity of air, and ſome vapours which will circulate for ſome time, and then condenſe in the veſſels. This

780 Clyſſus of nitre.

liquor is called *clyſſus of nitre*. If ſulphur is uſed inſtead of nitre, the clyſſus is of a different kind, conſiſting of a mixture of the nitrous and vitriolic acids. The reſiduum, when charcoal is uſed, is a very ſtrong and pure alkali; with ſulphur it is vitriolated tartar. To prevent the loſs occaſioned by the violent deflagration, when this operation is performed in open veſſels, Dr Black recommends to have the materials ſomewhat moiſt.

III. *By Vinous Spirits.* In the proceſs already mentioned for making *ſpiritus nitri dulcis*, a total decompoſition of the acid ſeems to take place: for neither the dulcified ſpirit itſelf, nor the acid matter left in the retort, ſhow any ſigns of deflagration with inflammable matters, which is the peculiar characteriſtic of nitrous acid.

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781 Reſiduum of ſpiritus nitri dulcis analized by Mr Pott.

Mr Pott has given an analyſis of the oleaginous reſiduum of the diſtillation. Diſtilled by a ſtronger fire, it gave over a yellow, acid, ſlightly empyreumatic ſpirit; which being ſaturated with fixed alkali, the liquor evaporated, and the dry neutral ſalt laid on burning coals, did not deflagrate. After this ſpirit aroſe a red empyreumatic oil; and in the bottom of the retort was left a ſhining black maſs like ſoot; which, burnt in a crucible, left a white fixed earth, convertible by a vehement fire into glaſs. Another parcel of the above reſiduum was evaporated to the conſiſtence of pitch. In this ſtate it gave a yellow tincture to ſpirit of wine, flamed vividly and quietly on burning coals, and at laſt ſwelled up like bitumen. Another portion was ſaturated with alkaline ley, with which it immediately effervesced, and then evaporated as the former. It gave, as before, a yellow colour to rectified ſpirit of wine, and a much deeper yellow to dulcified ſpirit of nitre; and in the fire diſcovered no footſtep of detonation. M. Macquer ſuppoſes this acid to have been not the nitrous, but the acetous, which enters into the compoſition of the ſpirit of wine; and his conjecture is now confirmed by late experiments.

§ 3. *Of the* MARINE *Acid and its Combinations.*

782 Marine acid.

THIS acid is never, at leaſt very rarely, found but in a ſtate of ſaturation with the mineral alkali; in which caſe it forms the common ſalt uſed in food. Almoſt the only exception to this is human urine, and perhaps that of ſome other animals; for there the marine acid is found ſaturated, not with the mineral, but the common vegetable, fixed alkali. From being found in ſuch plenty in the waters of the ocean, it has the name of *marine acid*.

783 Marine acid thought to be the ſame with the vitriolic.

It is commonly thought that this acid is no other than the vitriolic, ſomehow or other diſguiſed by the inflammable principle; to which ſome have added another, called by them a *mercurial earth*.

The reaſons given for this ſuppoſition, however, are but very ſlight, conſiſting chiefly in the reſemblance between the volatile vitriolic acid and the marine, both in the white colour of their vapours, and likewiſe the great volatility of both. As to the exiſtence of that principle called a mercurial earth, it hath never been proved; and, till that time, can never be allowed to be an ingredient in the compoſition of any ſubſtance whatever. As we do not remember to have read of any experiments where the marine acid was directly produced from that of vitriol, we ſhall content ourſelves with relating one very remarkable fact which happened to fall under our own obſervation.

784 A tranſmutation.

As vitriolated tartar, or Glauber's ſalt, when fuſed with charcoal duſt, is converted into an hepar ſulphuris, attempts have been made on this principle to ſeparate the pure alkali from the reſiduum of Glauber's ſpirit of nitre and ſpirit of ſalt. In an attempt of this kind, which, by the bye, proved unſucceſsful, as all others of the ſame kind muſt do, 30 or 40 pounds

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pounds of the maſs for Glauber's ſalt were fuſed in a ſtrong iron pot, with a ſufficient quantity of common coal powdered and ſifted. As the quantity of powdered coal was pretty large, the maſs was thereby hindered from flowing into thin fuſion; and, that the whole might be perfectly alkaliſated, it was frequently ſtirred up with an iron ladle, and kept very intenſely heated for ſome hours. The maſs was now taken out by means of an iron ladle, and laid on a flat ſtone; and, as it was but half fluid, every ladleful concreted into a black irregular ſaline maſs, which had the appearance of a cinder: but which, however, conſiſted of an hepar ſulphuris mixed with ſome coal-duſt. As there was a conſiderable quantity of this matter, and the ladlefuls were thrown at random above one another, it ſo happened, that between two or three of the pieces, a kind of chimney was formed, ſo that there being a ſmall draught of air through the interſtices, and the maſſes containing a quantity of coal-duſt, the internal parts were in a ſtate of ignition, while the external were quite cold. From theſe ignited places a white fume aroſe; which being collected on the colder maſſes, aſſumed the form of white flowers. Theſe were found to be genuine ſal ammoniac, compoſed of a volatile alkali and marine acid; both of which we have the greateſt reaſon to think were produced at that very time, and that a double tranſmutation took place; namely, of the vitriolic acid into the marine, and of the fixed alkali into the volatile. Our reaſons for being of this opinion are, 1. That the matter had been ſubjected to ſuch an extreme and long continued heat, that, had any ſal ammoniac been pre exiſtent in the mixture, it muſt have certainly been diſſipated, as this ſalt always ſublimes with a degree of heat below ignition. 2. Though the matter was taken out of the pot of a very intenſe red heat, ſo that the ſaline part was evidently melted, yet no ammoniacal fume iſſued from it at that time, nor till the maſſes had been for ſome time expoſed to the air, and were become cool, excepting only thoſe interſtices where the air kept up a burning heat, by a ſmall draught being formed from the ſituation of the ſaline maſſes. 3. In thoſe ignited places, when cool, the fixed ſalt was entirely decompoſed, neither alkaline ſalt, Glauber's ſalt, fixed alkali, nor ſulphur remaining; but the whole was conſumed to a kind of ferruginous aſhes. We are therefore of opinion, that the marine acid and volatile alkali are, in ſome caſes, mere creatures of the fire, and moſt commonly produced at the ſame time, from the ſlow combuſtion of mineral ſubſtances. Hence, where heaps of hot cinders are thrown out, ſmall quantities of the true ſal ammoniac are always formed, when the ignited ones happen to fall in ſuch a manner as to occaſion a ſmall draught of air through them.

785 Dr Prieſtley's obſervations on marine acid.

The marine acid, or ſpirit of ſalt, is weaker than either the vitriolic or nitrous; though Dr Prieſtley hath obſerved, that, when concentrated to the utmoſt degree, in which ſtate it was perfectly inviſible and elaſtic as air, it was then able to ſeparate the nitrous acid from an alkali. In ſome other caſes, too, it appears not only ſtronger than the nitrous, but even than the vitriolic; of which we ſhall take notice in courſe. —Mr Berthollet ſays, that he has been able alſo to procure the marine acid in a ſolid ſtate, by diſtilling it in Mr Woulfe's apparatus, kept perfectly cool with ice.

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The yellow colour of the marine acid is ſometimes owing to iron, which may be precipitated from it by means of an alkali. In certain caſes, however, it is obſerved to have a much darker and nearly a brown colour, without containing the ſmalleſt particle of this metal.—Mr Dollfuſs is of opinion, that the yellow colour of the marine acid is owing to a portion of dephlogiſticated air which it generally contains. A pretty ſtrong proof that it emits this kind of air indeed is, that a candle will burn longer in a bottle containing ſome marine acid, than it will in an equal quantity of common air.

I. To procure the Marine Acid by means of the *Vitriolic.*

786 Spirit of ſea-ſalt.

Put any quantity of ſea-ſalt into a tubulated glaſs-retort, to which a large receiver is firmly luted, having a quantity of water in it, more or leſs as you want your ſpirit of ſalt to be more or leſs ſtrong. Having placed your retort in a ſand-bath, take of concentrated oil of vitriol half as much as you put ſalt into the retort. Through the aperture in the upper part of the retort, pour a ſmall quantity of the vitriolic acid; a violent efferveſcence will immediately ariſe, and white vapours will aſcend, and come over into the receiver. Theſe vapours are the marine acid in its moſt concentrated ſtate; and, as they are very greedy of moiſture, they will unite with the water in a very ſhort time, unleſs too much oil of vitriol is put in at once; in which caſe, part of them will be diſſipated through the ſmall hole in the receiver. When you perceive the firſt fumes condenſed, add a little more oil of vitriol, taking care to ſtop the aperture of the retort as ſoon as you drop in the vitriolic acid, that the marine acid may not eſcape. Continue this by intervals, till your acid is all put in; and then make a very gentle fire, that the retort may be no warmer than the hand can bear. This degree of heat muſt be continued a long time, otherwiſe very much of the acid will be loſt. To perform this operation perfectly, no more acid ſhould be forced over, than what the water in the receiver can take up; and by this means the operator's patience will be rewarded with a vaſtly larger produce of acid than can be procured by haſty diſtillation. When the vapours become a little more fixed, a greater heat is neceſſary, but nothing equal to what the nitrous acid requires. For diſtilling ſpirit of ſalt, Mr Wiegleb recommends four pounds of oil of vitriol to ſix of common ſalt.—It may alſo be obtained from the bittern remaining after the cryſtallization of common ſalt, by adding one pound of oil of vitriol to five of bittern. It may even be obtained from this liquid by ſimple diſtillation without any additional acid; but a violent fire will then be neceſſary, and it is almoſt impoſſible to prevent the liquor from ſwelling and running over the neck of the retort in the beginning of the proceſs.

787 Why diſtillation of ſea-ſalt with copperas does not ſucceed.

The marine acid cannot be procured by means of combinations of the vitriolic acid with metallic and earthy baſes, as the nitrous is; for though, by means of calcined vitriol, for inſtance, the marine acid is effectually expelled from its alkaline baſis, yet it immediately combines with the calx of iron left by the vitriolic acid, and not only adheres obſtinately, but even ſublimes the metal; ſo that what little ſpirit can be ob-

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obtained, is never pure. This inconvenience is not so great when uncalcined copperas is made use of: for the marine acid has a very strong attraction to water; which partly dissolves its union with the metalline calx. If gypsum is used, instead of calcined vitriol, not a drop of spirit will be obtained. Alum and sal catharticus amarus answer better.

II. To procure the Marine Acid by means of the *Nitrous*.

788 Aqua-regis. Take equal quantities of sea-salt and Glauber's spirit of nitre; put the salt into a retort, and pour on it the nitrous acid; let them stand for 10 or 12 hours; then distil with a gentle heat; an acid liquor will come over, which is a compound of the nitrous and marine acids, called *aqua-regis*. When the distillation is finished, and the vessels cooled, pour back the distilled liquor on the mass which is left on the retort, and distil again: the second produce will be more of the nature of spirit of sea-salt than the former. Continue to do this, pouring the distilled liquor either on the mass left in the retort, or upon fresh sea-salt, till you observe that no nitrous acid arises. No experiments have been made on this spirit of salt, by which we can judge whether it is different from that procured by the vitriolic acid or not.

III. To procure the Marine Acid, by distilling Salt *per se*.

789 Spirit of salt *per se*. Put into a retort any quantity of common salt which has not been dried, and distil in a sand-heat till nothing more will come over. In the receiver you will have a liquor considerably more acid than vinegar, in weight about the fourth part of the salt employed. On the dry salt left in the retort, pour some water, somewhat less in quantity than the liquor which came over. Let it stand till the salt has thoroughly imbibed the moisture, and then distil again. You will again have an acid, but weaker than the former. Repeat this six or seven times; after which you will obtain no more marine acid in this way. It has been thought that sea-salt was capable of total decomposition by means of moisture alone; but that is found to be a mistake. The reason of any acid being procurable in this way, is the impurity of the common salt, which is always mixed with a quantity of sal catharticus amarus, and of marine acid combined with magnesia, from which last it is separable by moisture. If a pure salt be formed by combining marine acid with salt of soda, no spirit will be obtained.

IV. To dephlogisticate the Marine Acid.

790 Marine acid dephlogisticated by that of nitre or by manganese. The marine acid, when mixed either with that of nitre or with manganese, loses that peculiar smell by which it is usually distinguished, and acquires one much more volatile and suffocating. When mixed with the former, the compound is called *aqua-regia*; when subjected to the action of manganese, the product is called *dephlogisticated spirit of salt*. The method of procuring

791 Scheele's method of dephlogisticating it by manganese. this acid recommended by Mr Scheele is as follows: Mix common muriatic acid in any quantity with levigated manganese in a glass retort; to which lute on with blotting paper a receiver capable of containing about 12 ounces of water. Put about two drachms of liquid into it; and in about a quarter of an hour, or somewhat more, a quantity of elastic fluid, which is the true dephlogisticated spirit of salt, will pass over, and communicate a yellow colour to the air in the receiver; after which the latter is to be separated from the retort. If the paper has been closely applied, a quantity of the air will now rush out with some violence; a cork must therefore instantly be put into it, and another receiver applied, having in like manner two drachms of water in it, which will also be filled in a short time; and thus may several phials full of this aerial acid be procured in a short time. Care should be taken, that the retort be placed in such a manner as that any drops of liquid which chance to arise may fall down again into it. The water put into the receivers seems to condense the vapours of the marine acid; and it is most proper to use small receivers, on account of the great quantity of vapour which is lost at every operation.

792 Properties of dephlogisticated spirit of salt. The effects of this dephlogisticated marine acid, which can scarcely be condensed into a liquid, are, 1. The lute is corroded in distillation, and the corks become yellow, as from aquafortis. 2. Paper coloured with lacmus becomes nearly white, as well as all vegetable red, blue, and yellow flowers; and the same change is likewise produced upon the green colour of vegetables; nor can any of these colours be recovered either by alkalies or acids. 3. Expressed oils and animal fats, exposed to the vapour, become as tenacious as turpentine. 4. Cinnabar grew white on the surface; and when it was washed, a pure solution of corrosive sublimate was obtained; but sulphur was not changed. 5. Green vitriol became red and deliquescent; but white and blue vitriol remained unchanged. 6. Iron filings were dissolved; and on evaporating the solution to dryness, common muriatic acid was obtained by distillation with marine acid. 7. In like manner all the metals, even gold itself, were dissolved; and by precipitation with volatile alkali, the solution of gold yielded aurum fulminans. 8. The caustic volatile alkali produced a white cloud, and emitted a number of air-bubbles, which on bursting discharged an elastic vapour. 9. Fixed alkali was changed into common salt, which decrepitated in the fire. 10. Arsenic became deliquescent, insects died, and fire was instantaneously extinguished in the vapour.

793 Mistake of Stahl accounted for. These phenomena proceed from the strong attraction of dephlogisticated marine acid for the phlogiston it has lost; and which is one of the essential parts of it, without which it can scarce at all be condensed into a liquor. "Perhaps (says Mr Scheele) Stahl obtained such a dephlogisticated muriatic acid by means of iron; and from the yellow colour of the cork was led to suppose that the muriatic acid had been changed into the nitrous. If you make a mixture of manganese, muriatic acid, or diluted vitriolic acid, and alcohol; and after some days digestion distil it by a gentle fire, no effervescence ensues: but the spirit of wine goes over; and, what is very remarkable, has a strong smell of nitrous ether.

2d 793 New salt resembling nitre by Mr Berthollet. A new salt has been produced by Mr Berthollet from the union of dephlogisticated spirit of salt with vegetable alkali. This appears to be of the nitrous kind, as having a cool taste and detonating strongly in the fire. The compound was in very small quantity, and seemed to require more pure air for its composition than an equal bulk of acid. The greatest part of the salt produced was the common salt of Sylvius, or digestive salt, formed by a combination of the phlogisticated marine

Marine acid and its combinations.

rine acid with alkali. Six parts of the dephlogisticated acid are required to give their air to one of the salt. When the fixed alkali is employed, some of the dephlogisticated acid escapes with the pure air; and in general, when not exposed to a bright heat, the salt we speak of is formed. Some of the dephlogisticated acid remains in its proper form after the salt is made, and may be separated by the volatile alkali. It is to be observed, that if the caustic alkali be employed, and the solution much concentrated, even though not under the influence of a bright light (for it is the light which produces the extrication of the dephlogisticated air*), a great effervescence will ensue, and a quantity of dephlogisticated air escape; whence of consequence, little salt can be obtained.

* See *Aërology*, n° 36, *et seq.*

This salt is soluble in greater quantity in hot than in cold water; and not only detonates like nitre, but with much greater violence. The reason is, that, like nitre, it not only contains dephlogisticated air, but has it in greater quantity; an hundred grains of salt giving 75 of air. Attempts have been made to procure gunpowder by means of this salt, but as yet they have been attended with little success.

The other properties of this salt as yet discovered are, that it shoots into rhomboidal crystals; it does not precipitate mercury, silver, or lead, from their solutions in nitrous acid; and it gives out its air again in such a pure state as scarcely to be paralleled in any other substance.

With the mineral alkali the dephlogisticated acid forms a deliquescent salt, soluble in spirit of wine; and which, even in a fluid state, detonates with burning charcoal. With lime, when so far quenched that the air in its interstices is separated, the dephlogisticated acid unites but weakly. It may be recovered from the lime, however, provided the light be obscure, with very little loss, and almost unchanged.

Marine Acid COMBINED,

794 Sal digestivus sylvii.

I. *With Vegetable Fixed Alkali.* This combination is accidentally formed after the distillation of volatile salts, by means of salt of tartar (see *Alkaline Salts*). It was formerly known by the name of *sal digestivus Sylvii*; and a process for making it was inserted in the dispensatories, under the name of *spiritus salis marini coagulatus*; but as it has been found to possess no virtues superior, or even equal, to common salt, it is fallen into disuse.

The crystals of this kind of salt are not cubical, like those of common salt, but parallelopipeds, and if thrown into the fire crack and leap about with violence. They are soluble in greater quantity by hot water than cold; and therefore are crystallized by evaporating the solution to a pellicle, and then letting it cool.—It is very remarkable, that though by a direct combination of vitriolic acid with vegetable fixed alkali, the salt called *vitriolated tartar* is formed; yet if this alkali is once saturated with spirit of salt, so as to form a *sal digestivus*, upon the decomposition of this salt by means of oil of vitriol, the residuum of the distillation will not be a vitriolated tartar, but a salt easily soluble in water, and which bears a strong resemblance to Glauber's salt. Whether, by means of spirit of sea-salt, the vegetable alkali could be converted into the mineral, or salt of soda, is a question well worthy of being solved.

II. *With Mineral Alkali.* This combination is the common alimentary salt, and is never made but for experiment's sake; as the marine acid cannot be had but from sea-salt. For the extraction of this salt from sea-water, see the article SALT.

795 Sal ammoniac.

III. *With Volatile Alkali.* The produce of this combination is the common sal ammoniac, which is used in different arts, and which has the property of making tin unite very readily with iron and copper, so is much used by coppersmiths and in the manufactory of tinned iron.

Sal ammoniac is usually sold in large semi-transparent cakes, which are again capable of being sublimed into masses of the like kind. If they are dissolved in water, the salt very easily shoots into small crystals like feathers. Exposed to a moist air, it deliquates. It is one of the salts which produces the most cold by its solution; so as to sink the thermometer 18 or 20 degrees, or more, according to the temperature of the atmosphere. According to Mr Gellert, a solution of sal ammoniac has the property of dissolving resins. According to Neumann, the volatility of sal ammoniac is so much diminished by repeated sublimations, that at last it remains half fluid in the bottom of the subliming vessel. In its natural state, it sublimes with a degree of heat necessary to melt lead. Pott says, that a small quantity of sal ammoniac may be produced by distilling sea-salt with charcoal, or with alum, or by distilling marine acid with Armenian bole. The same author affirms, that the inflammability of sulphur is destroyed by subliming it with twice its quantity of sal ammoniac.

796 How made.

The method of making this salt was long unknown; and it was imported from Egypt, where it was said to be prepared by sublimation from soot alone, or from a mixture of sea-salt, urine, and soot. That it should be produced from soot alone is very improbable; and the other method, from the known principles of chemistry, is absolutely impossible. The composition of this salt, however, being once known, there remained no other desideratum than a method of procuring those competent parts of sal ammoniac sufficiently cheap, so as to afford sal ammoniac made in Britain at a price equally low with what was imported. The volatile alkali is to be procured in plenty from animal substances or from soot; and the low price of the vitriolic acid made from sulphur affords an easy method of decomposing sea-salt, and obtaining its acid at a low rate. A sal ammoniac work has, accordingly, been established for several years past in Edinburgh; the principal material made choice of for procuring the volatile alkali is soot; and though no persons are admitted to see the work, the large quantities of oil of vitriol brought into it, and the quantities of genuine *sal mirabile* which are there made, evidently show that the process for making sal ammoniac also produces Glauber's salt, by the decomposition of common salt by means of vitriolic acid. The method of conducting the process is unknown; but it is plain that there can be no other difficulty than what arises from the volatility of the vapours of the alkali and of the marine acid. In the common way of distilling those substances, a great part of both is lost; and if it is attempted to make sal ammoniac by combining these two when distilled by the common apparatus, the pro-

duce

Marine acid and its combinations. duce will not pay the coſt; a little ingenuity, however, will eaſily ſuggeſt different forms and materials for diſtilling-veſſels, by which the marine acid and volatile alkali may be united without loſing a particle of either.

If a ſolution of vitriolic or Glauber's ſecret ſal ammoniac is mixed with ſea-ſalt, the vitriolic acid ſeizes the alkaline baſis of the ſea-ſalt, and expels the marine acid; which immediately unites with the volatile alkali left by the vitriolic acid, and forms a true ſal ammoniac. If this ſolution is now evaporated to dryneſs, and the ſaline maſs ſublimed, the ſal ammoniac riſes, and leaves a combination of vitriolic acid and mineral alkali at the bottom. This fixed maſs being diſſolved, filtered, and evaporated, affords Glauber's ſalts. This has ſometimes been thought a preferable method of making ſal ammoniac, as the trouble of diſtilling the marine acid was thereby prevented; but it is found vaſtly inconvenient on another account, namely, that when ſal ammoniac is mixed with any fixed ſalt, it is always more difficult of ſublimation, and a part of it even remains entirely fixed, or is deſtroyed. The maſs of Glauber's ſalt alſo, by reaſon of the inflammable and oily matter contained in impure volatile alkalies, is partly changed into a ſulphureous maſs, ſo that the ſolution refuſes to cryſtallize; at leaſt the operation is
797 Fixed ſal ammoniac. attended with intolerable trouble.

IV. *With Earths.* The combinations of this acid with earths of any kind have never been found applicable to any purpoſe, and therefore they are ſeldom made or inquired into. The combination with calcareous earth is indeed pretty frequently made accidentally, in
798 Phoſphorus. the diſtillation of volatile alkali from ſal ammoniac by means of chalk or quicklime. When melted in a crucible and cooled, it appears luminous when ſtruck, and has been called *phoſphorus ſcintillans.* See EARTHS.

799 Solution of gold in ſpirit of ſalt. V. *With Gold.* The marine acid has no action on gold in its metallic ſtate, in whatever manner the acid be applied; but if the metal is previouſly attenuated, or reduced to a calx, either by precipitation from aqua-regis or by calcination in mixture with calcinable metals, this acid will then perfectly diſſolve, and keep it permanently ſuſpended. Gold, precipitated from aqua-regis by fixed alkalies, and edulcorated by repeated ablutions, may be diſſolved even in a very weak ſpirit of ſalt by moderate digeſtion. This ſolution appears of the ſame yellow colour as that made in aqua-regis; gives the purple ſtain to the ſkin, feathers, bones, and other ſolid parts of animals; the ſame violet ſtain to marble; and ſtrikes the ſame red colour with tin. Even when common aqua-regia is made uſe of for the menſtruum, it ſeems to be chiefly by the marine acid in that compound liquor that the gold is held in ſolution. In diſtillation the nitrous acid ariſes, and the marine acid remains combined with the gold in a blood-red maſs, ſoluble, like moſt of the combinations of metallic bodies with this acid, in ſpirit of wine. If, towards the end of the diſtillation, the fire is haſtily raiſed, part of the gold diſtils in a high ſaffron-coloured liquor; and part ſublimes into the neck of the retort in cluſters of long ſlender cryſtals of a deep red colour, fuſible in a ſmall heat, deliquating in the air, and eaſily ſoluble in water. By repetitions of this proceſs the whole of the gold may be elevated, except a ſmall quantity of white powder whoſe nature is not known. Marine acid and its combinations
—This red ſublimate of gold is ſaid to be eaſily fuſible with the heat of one's hand, and to be ſhown by the Papiſts for the blood of St Januarius; the ſublimate contained in a phial, being warmed by the hands of 800
the prieſts who hold it, conſtitutes the miracle of that Blood of St Januarius.
ſaint's blood melting on his birth-day.

VI. *With Silver.* Strong ſpirit of ſalt corrodes leaf- 801 Silver.
ſilver into a white powder, but has no effect on filings or larger maſſes of the metal. If applied in the form of vapour to maſſes of ſilver, and ſtrongly heated at the ſame time, it readily corrodes them. Thus, if filings, grains, or plates, of ſilver are mixed with about twice their weight of mercury ſublimate, and expoſed to a moderate fire, in a retort, or other diſtilling veſſel, a part of the marine acid in the ſublimate will be ſeparated and unite with the ſilver, leaving the mercury to ariſe in the form of mercurius dulcis. Marine acid is commonly ſuppoſed to be incapable of diſſolving ſilver into a liquid ſtate; but Henckel relates, that if red ſilver ore, which conſiſts of ſilver intimately mixed with red arſenic, be digeſted in ſpirit of ſalt, the ſilver will be extracted and kept permanently diſſolved. 802

The combination of marine acid with ſilver is called Luna cornea.
luna cornea. The moſt ready way of preparing it is by diſſolving ſilver in the nitrous acid, and then adding ſpirit of ſalt, or a ſolution of ſea-ſalt, when a precipitation inſtantly enſues; the marine acid expels the nitrous, and uniting with the ſilver, falls to the bottom in form of a white powder. The ſame precipitation would take place, if a ſolution of ſilver was made in the vitriolic acid. 803

Luna cornea weighs one-fourth more than the ſilver Its properties.
employed; yet, when perfectly waſhed, it is quite inſipid to the taſte. It does not diſſolve in water, ſpirit of wine, aqua-fortis, or aqua-regis; but is in ſome ſmall degree acted upon by the vitriolic acid. It melts in the fire as ſoon as it grows red-hot; and, on cooling, forms a ponderous browniſh maſs, which being caſt into thin plates, becomes ſemitranſparent, and ſomewhat flexible, like horn; whence its name *luna cornea.* A ſtronger fire does not expel the acid from the metal, the whole concrete either ſubliming entire, or paſſing through the crucible. It totally diſſolves in volatile alkaline ſpirits without any ſeparation of the metal. Expoſed to the fire in a cloſe copper veſſel, it penetrates the copper, and tinges it throughout of a ſilver colour. Kunckel obſerves, that when carefully prepared, melted in a glaſs veſſel, and ſuffered to cool ſlowly, to prevent its cracking, it proves clear and tranſparent; and may be turned into a lathe and formed into elegant figures. He ſuppoſes this to be the preparation which gave riſe to the notion of malleable glaſs. 804

VII. *With Copper.* In the marine acid, copper diſ- Copper.
ſolves but ſlowly. The ſolution, if made without heat, appears at firſt brown; but, on ſtanding for ſome time, depoſits a white ſediment, and becomes green. On adding freſh copper, it becomes brown again, and now recovers its greenneſs more ſlowly than before. The white ſediment, on being barely melted, proves pure and perfect copper of the ſame colour as at firſt. Copper calcined by fire communicates a reddiſh colour to this acid. 805

VIII. *With Iron.* The marine acid acts upon iron Iron.
leſs

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lefs vehemently than the nitrous, and does not diffolve fo much; neverthelefs, it attacks the metal brifkly, fo as to raife confiderable heat and effervefcence, and diffolve it into a yellow liquor. During the folution, an inflammable vapour arifes as in the folution of this metal by vitriolic acid. This folution of iron does not cryftallize. If it is evaporated, it leaves a greenifh
806 Iron volatilized. faline mafs, which is foluble in fpirit of wine, and runs in the air into a aftringent yellow liquor. On diftillation, fome of the acid feparates, and towards the end of the operation the fpirit becomes yellow. This is followed by a yellowifh, or deep reddifh fublimate, which gliftens like the fcales of fifhes; leaving behind a fubftance which confifts of thin, gloffy plates, like talc.

807 Tinctura martis.

The folution of iron in fpirit of falt, with the addition of fome fpirit of wine, is ufed in medicine as a corroborant, under the name of *tinctura martis*. The fublimate of iron is alfo ufed for the fame purpofe, and called *ens veneris*, or *flores martiales*. It is commonly directed to be prepared by fubliming iron filings and fal ammoniac together. In the procefs, the
808 Flores martiales. fal ammoniac is partly decompofed, and a cauftic alkaline liquor diftils. Then the undecompofed fal ammoniac, and the martial fublimate abovementioned, arife together. The fublimate has a deeper or lighter yellow colour, according as it contains more or lefs iron. The name *ens veneris* is improper. It was given by Mr Boyle, who difcovered this medicine. He imagined it to be a preparation of copper, having made ufe of a colcothar of vitriol containing both iron and copper. A me-
2d 808 Beftuchef's nervous tincture. dicine of this kind was lately fold with great reputation on the Continent, under the name of *Beftuchef's nervous tincture*. It was introduced by M. Beftuchef Field Marfhal in the Ruffian fervice: but not long after it came into vogue in Pruffia and other northern kingdoms of Europe: it made its appearance alfo in France, under the name of *General de la Motte's golden drops*. This happened through the infidelity of Beftuchef's operator, who, for a fum of money, violated the oath of fecrecy he had taken to Beftuchef, and difcovered the fecret to de la Motte. To the latter it proved a very valuable acquifition; for he not only procured a patent for it from the king of France in 1730, with the exclufive privilege of felling it, but had a handfome penfion fettled upon him; felling his medicine befides a half a Louis d'or per phial.

3d 808 Miftakes concerning it.

The attention of the public was particularly drawn to thefe drops, by their remarkable property of lofing their yellow colour in the fun, and regaining it in the fhade, which induced many to believe that they contained gold; and in which opinion they were encouraged by de la Motte. Even chemifts of no little reputation were deceived by this appearance; and M. Beaumé, imagining he had difcovered the fecret, publifhed a preparation to the world as the true arcanum of la Motte's drops. It confifted of a calx of gold precipitated from aqua-regia by means of fixed alkali, and rediffolved in nitrous acid, to which was added a large quantity of fpirit of wine. Others, however, who could find nothing but iron by an analyfis
4th 808 True method of preparing it. of the drops, refufed their affent; and at length, in 1780, M. Beaumé's miftake was made evident by the publication of the procefs at the defire of the emprefs of Ruffia, who gave 3000 rubles for the receipt. The original *recipe* is perplexed, tedious, and expenfive; but when deprived of its fuperfluous parts, is nearly as follows. Six pounds of common pyrites and twelve of corrofive fublimate are to be triturated together, and then fublimed fix or eight times till all the mercury is expelled. The refiduum is to be boiled three times with thrice its quantity of water, and as often filtered, and laftly, diftilled to drynefs. By increafing the fire, a martial falt is at laft fublimed into the neck of the retort; to three drachms of which are to be added 12 ounces of highly rectified fpirit of wine, and the whole expofed to the rays of the fun. This is the yellow tincture; but there was alfo a white one, which, however, feems to be but of little value. It is made by pouring on the refiduum of the laft fublimation twelve pounds of highly rectified fpirit of wine, and drawing it off by a gentle diftillation after a few 5th 808 Suppofed to abforb phlogifton from the fun's rays.
days digeftion.—Mr Klaproth imagines, from the following experiment, that Beftnchef's tincture abforbs phlogifton from the rays of the fun. He poured a few drops of a folution of tartar into two ounces of diftilled water, and divided this into two parts. Into one glafs having poured a few drops of the tincture that had not been expofed to the fun, the iron was precipitated in the ufual form of a yellow ochre; but on treating in the fame manner a portion of the tincture that had been expofed to the folar rays, the precipitate fell of a bluifh green colour. 809

IX. *With Tin.* Though the concentrated marine acid has a greater attraction for tin than any other acid, it does not readily diffolve this metal while the acid is in its liquid ftate; but may be made to diffolve it perfectly by the addition of a fmall quantity of fpirit of nitre. Neumann obferves, that an ounce of fpirit of falt, with only a fcruple of fpirit of nitre, diffolved tin perfectly: but on inverting the proportions, and taking a fcruple of marine acid to an ounce of the nitrous, four fcruples, or four and an half, of tin, were diffolved into a thick pap; fome more of the marine acid being gradually added, the whole was diffolved into a clear liquor. In making thefe folutions, a fmall quantity of black matter ufually fubfides. Solution of tin.

The folution of tin is fometimes colourlefs; fometimes of a bluifh, or yellow colour, according to different circumftances of the procefs. It is of the greateft confequence in dyeing, by not only heightening the colours, but making them more durable (See DYEING). It fhoots into fmall cryftals; and, if infpiffated, deliquates in the air. 810

Marine acid in its concentrated ftate volatilizes tin, and forms with it a thick liquor, which, from its inventor, is called *fmoking liquor of Libavius*. To prepare this fmoking liquor, an amalgam muft be made of four parts of tin and five of mercury. This amalgam is to be mixed with an equal weight of corrofive mercury, by triturating the whole together in a glafs mortar. The mixture is then to be put into a glafs retort, and the diftillation performed with a fire gradually increafed. A very fmoking liquor paffes into the receiver; and towards the end of the diftillation, a thick, and even concrete matter. When the operation is finifhed, the liquor is to be poured quickly into a cryftal glafs-bottle, with a glafs ftopper. When this bottle is opened, a white, copious, thick, the poignant fume iffues, which remains long in the air without difappearing. Smoking liquor of Libavius.

The acid in this liquor is far from being faturated, and

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and is capable of still dissolving much tin in the ordinary way. From this imperfect saturation, together with its concentration, proceeds partly its property of smoking so considerably: nevertheless, some other cause probably concurs to give it this property; for though it smokes infinitely more than the most concentrated spirit of salt, its vapours are, notwithstanding, much less elastic. It has all the other properties of concentrated marine acid when imperfectly saturated with tin. If it is diluted with much water, most of the metal separates in light white flocks. In dyeing, it produces the same effects as solution of tin made in the common way. If the distillation is continued after the smoking liquor of Libavius has come over, the mercury of the corrosive sublimate will then arise in its proper form.

811 Lead.

X. *With Lead.* Marine acid, whether in its concentrated or diluted state, has little effect upon lead, unless assisted by heat. If spirit of salt is poured on filings of lead, and the heat is increased so as to make the liquor boil and distil, a part of the acid will be retained by the metal, which will be corroded into a saline mass; and this, by a repetition of the process, may be dissolved into a limpid liquor. If lead is dissolved in aquafortis, and spirit of sea-salt, or sea-salt itself, added, a precipitation of the metal ensues; but if some aqua-regia is added, the precipitate is redissolved.

812 Plumbum corneum.

The combination of lead with marine acid, has, when melted, some degree of transparency and flexibility like horn; whence, and from its resemblance to luna cornea, it is called *plumbum corneum.* This substance is used in preparing phosphorus, according to Mr Margraaf's method.

813 Quicksilver.

XI. *With Quicksilver.* Marine acid in its limpid state, whether concentrated or diluted, has no effect upon quicksilver, even when assisted by a boiling heat; but if mercury is dissolved in the vitriolic or nitrous acids, and sea-salt, or its spirit, is added to the solution, it immediately precipitates the quicksilver in the same manner as it does silver or lead.

814 Corrosive sublimate.

If concentrated marine acid, in the form of vapour, and strongly heated, meets with mercury in the same state, a very intimate union takes place; and the produce is a most violent corrosive and poisonous salt, called *corrosive sublimate mercury.* This salt is soluble, though sparingly, in water; but is far from being perfectly saturated with mercury; for it will readily unite with almost its own weight of fresh quicksilver, and sublime with it into a solid white mass (which, when levigated, assumes a yellowish colour) called *mercurius dulcis, aquila alba,* or *calomel.*

815 Different methods of making.

There have been many different ways of preparing corrosive mercury, recommended by different chemists. Neumann mentions no fewer than ten. 1. From mercury, common salt, nitre, and vitriol. 2. From mercury, common salt, and vitriol. 3. Mercury, common salt, and spirit of nitre. 4. Solution of mercury in aquafortis, and salt. 5. Solution of mercury in aquafortis, and spirit of salt, or the white precipitate. 6. Mercury, common salt, nitre, and oil of vitriol. 7. Edulcorated turbith mineral, and common salt. 8. Red precipitate, common salt, and oil of vitriol. 9. Edulcorated turbith mineral, and spirit of salt. 10. Mercury, sal ammoniac, and oil of vitriol.

From a view of these different methods, it is evident, that the intention of them all is to combine the marine acid with quicksilver; and as this combination can be effected without making use of the nitrous acid, the greatest chemists have imagined that this acid, which is by far the most expensive of the three, might be thrown out of the process altogether, and the sublimate be more conveniently made by directly combining marine acid and mercury in a process similar to the distillation of spirit of salt. This method was formerly recommended by Kunckel; then published in the memoirs of the Academy of Sciences for 1730; and has been adopted and recommended by Dr Lewis.

The process consists in dissolving mercury in the vitriolic acid, as directed for making turbith mineral. The white mass remaining on the exsiccation of this solution is to be triturated with an equal weight of dried salt, and the mixture is then to be sublimed in a sand-heat; gradually increasing the fire till nothing more arises. 816

Differences of quality.

Neumann observes, that there is a considerable difference in the quality of sublimates made by the different methods he mentions; particularly in those made with or without nitre. This we have also found to be the case; and that sublimate made without the nitrous acid is never so corrosive, or soluble in water, as that which is made with it: nor will it afterwards take up so large a quantity of crude mercury as it otherwise would, when it is to be formed into calomel. The above process, therefore, tho' very convenient and easy, is to be rejected; and some other in which the nitrous acid is used, substituted in its stead. The reason of these differences is, that the spirit of salt must by some means or other be dephlogisticated before it can unite in sufficient quantity with the metal, into the compound desired, which is accomplished by the addition of nitrous acid.

From Tachenius, Neumann gives us the following process, which he says was the method of making sublimate at London, Venice, and Amsterdam. Two hundred and eighty pounds of quicksilver, 400 pounds of calcined vitriol, 200 pounds of nitre, the same quantity of common salt, and 50 pounds of the caput mortuum remaining after a former sublimation, or (in want of it) of the caput mortuum of aquafortis, making, in all, 1130 pounds, are well ground, and mixed together; then set to sublime in proper glasses placed in warm ashes, the fire is increased by degrees, and continued for five days and nights. In the making such large quantities, he says, some precautions are necessary, and which those constantly employed herein are best acquainted with. The principal are, the due mixture of the ingredients, which in some places is performed in the same manner as that of the ingredients for gun-powder: that a head and receiver be adapted to the subliming glass, to save some spirit of nitre which will come over. (Here a bent tube of glass will answer the purpose, as already mentioned). The fire must not be raised too hastily. When the sublimate begins to form, the ashes must be removed a little from the sides of the glass, or the glass cautiously raised up a little from the ashes. (This last, we think, is highly imprudent.) Lastly, the laboratory must have a good chimney, capable of carrying off the noxious fumes. The above-mentioned quantities commonly yield 360 pounds of sublimate; the 280 pounds of quicksilver gaining 80 from the 200 pounds of sea-salt. The makers of sub-

limate

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limate in France, he says, employ, in one operation, only 20 pounds of mercury. This they dissolve in aquafortis, evaporate the solution to dryness, mix the dry matter with 20 pounds of decrepitated sea-salt and 60 of calcined vitriol, and then proceed to sublimation.

817 Observations on the different methods.

The above processes, particularly the last, are unexceptionable as to the production of a sublimate perfectly corrosive; but the operation, it is evident, must be attended with considerable difficulty, by reason of the large quantity of matter put into the glass at once. We must remember, that always on mixing a volatile salt with a quantity of fixed matter, the sublimation of it becomes more difficult than it would have been had no such matter been mixed with it. It is of considerable consequence, therefore, in all sublimations, to make the quantity of matter put into the glass as little as possible. It would seem more proper, instead of the calcined vitriol used in the processes last mentioned, to dissolve the mercury in the vitriolic acid, as directed in turbith mineral, and sublime the dry mass mixed with nitre and sea-salt.

818 Supposed adulteration with arsenic.

It has been said, that corrosive sublimate mercury was frequently adulterated with arsenic; and means have even been pointed out for detecting this supposed adulteration. These means are, to dissolve a little of the suspected salt in water, and add an alkaline lixivium to precipitate the mercury. If the precipitate was of a black colour, it was said to be a certain sign of arsenic. This, however, shows nothing at all, but that either the alkali contains some inflammable matter, which, joining with the precipitate, makes it appear black; or that the sublimate is not perfectly corrosive; for if a volatile alkali is poured on levigated *mercurius dulcis*, the place it touches is instantly turned black.

819 Mercurius dulcis.

Mercurius dulcis, or calomel, is prepared by mixing equal parts, or at least three of quicksilver with four of sublimate; after being thoroughly ground together in a glass or stone mortar, they are to be poured through a long funnel into a bolt-head, and then sublimed. The medicine has been thought to be improved by repeated sublimations, but this is found to be a mistake. Mr Beaumé has found that mercurius dulcis cannot be united with corrosive sublimate in the way of sublimation; the former, by reason of its superior volatility, always rises to the top of the vessel.

820 Zinc volatilized.

XII. *With Zinc.* This semimetal dissolves readily in the marine acid into a transparent colourless liquor. It is volatilized, as well as most other metallic substances by this combination, as appears from the following process delivered by Neumann.

"Equal parts of filings of zinc and powdered sal ammoniac being mixed together, and urged with a gradual fire in a retort; at first arose, in a very gentle heat, an excessively penetrating volatile spirit, so strong as to strike a man down who should inadvertently receive its vapour freely into the nose. This came over in subtile vapours, and was followed by a spirit of salt in dense white fumes. In an open fire, white flowers succeeded; and at length a reddish and a black butter. In the bottom of the retort was found a portion of the zinc in its metallic form, with a little ponderous and fixed butyraceous matter which liquefied in the air. The lump was far more brittle than zinc ordinarily is; of a reddish colour on the outside, and blackish within. The bottom of the retort was variegated with yellow and red colours, and looked extremely beautiful. The remaining zinc was mixed afresh with equal its weight of sal ammoniac, and the process repeated. A volatile alkaline spirit and marine acid were obtained as at first; and in the retort was found only a little black matter. When the zinc was taken at first in twice the quantity of the sal ammoniac, the part that preserved its metallic form proved less brittle than in the foregoing experiment, and the retort appeared variegated in the same manner. On endeavouring to rectify the buttter, the retort parted in two by the time that one half had distilled." The nature of this combination is unknown.

821 Butter of antimony.

XIII. *With Regulus of Antimony.* This semimetal cannot be united with the marine acid unless the latter is in its most concentrated state. The produce is an excessively caustic thick liquid, called *butter of antimony.* The process for obtainining this butter is similar to that for distilling the smoking spirit of Libavius. Either crude antimony, or its regulus, may be used: for the spirit of salt will attack the reguline part of this mineral without touching the sulphureous. Three parts of corrosive sublimate are to be mixed with one of crude antimony; the mixture to be digested in a retort set in a sand-heat; the marine acid in the sublimate will unite with the reguline part of the antimony. Upon increasing the fire, the regulus arises, dissolved in the concentrated acid, not into a liquid form, but that of a thick unctuous substance like butter, from whence it takes its name. This substance liquefies by heat, and requires the cautious application of a live coal to melt it down from the neck of the retort. By rectification, or exposure to the air, it becomes fluid like oil but still retains the name of butter. If water is added to butter of antimony, either when in a butyraceous form, or when become fluid by rectification, the antimony is precipitated in a white powder called *powder of algaroth*, and improperly *mercurius vitæ*. This powder is a violent and very unsafe emetic. The butter itself was formerly used as a caustic; but it was totally neglected in the present practice, until lately that it has been recommended as the most proper material for preparing emetic tartar. (See below.) Mr Dollfuss recommends the following method as the best for making butter of antimony; *viz.* two ounces and a quarter of the grey calx of antimony, eight ounces of common salt, and six of acid of vitriol. By distilling this mixture, ten ounces of the antimonial caustic were obtained; and in order to determine the quantity of metal contained in it, he mixed two ounces of the caustic with four ounces of water; but thus such a strong coagulum was formed, that he was not able to pour off any of the water even after standing 24 hours. The precipitate, when carefully dried, weighed 50 grains. The result was much the same when glass of antimony was used, only that the precipitate was much more considerable, half an ounce of the caustic then yielding 60 grains, though at another time only 50 grains were obtained. In the re-

siduum

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When the mercurius vitæ precipitates, the union between the marine acid and regulus is totally diffolved; fo that the powder, by frequent wafhings, becomes perfectly free from every particle of acid, which unites with the water made ufe of, and is then called very improperly, *philofophic fpirit of vitriol.*

822 Sympathetic ink. XIV. *With Regulus of Cobalt.* Pure fpirit of falt diffolves this femimetal into a reddifh yellow liquor, which immediately becomes green from a very gentle warmth. On faturating the folution with urinous fpirits, the precipitate appears at firft white, but afterwards becomes blue, and at length yellow. If the nitrous acid is added to folutions of regulus of cobalt, they affume a deep emerald green when moderately heated, and on cooling become red as at firft. Duly evaporated, they yield rofe-coloured cryftals, which change their colour by heat in the fame manner. This folution makes a curious fympathetic ink, the invention of which is commonly afcribed to M. Hellot, though he himfelf acknowledges that he received the firft hint of it from a German chemift in 1736. Any thing wrote with this folution is invifible when dry and cold; but affumes a fine green colour when warm, and will again difappear on being cooled; but if the heat has been too violent, the writing ftill appears. M. Hellot obferves, that if nitre or borax be added to the nitrous folution, the characters wrote with it become rofe-coloured when heated, and if fea-falt is afterwards paffed over them, they become blue; that with alkali fufficient to faturate the acid, they change purple and red with heat.—A blue fympathetic ink may be made from cobalt in the following manner. Take of an earthy ore of cobalt, as free from iron as poffible, one ounce. Bruife it, but not to too fine a powder. Then put it into a cylindrical glafs, with 16 ounces of diftilled vinegar, and fet the mixture in hot fand for the fpace of fix days, ftirring it frequently; or elfe boil it directly till there remain but four ounces. Filter and evaporate it to one half. If your folution be of a rofe colour, you may be certain that your cobalt is of the right fort. A red brown colour is a fign of the folution containing iron; in which cafe the procefs fails. To two ounces of the folution thus reduced, add two drachms of common falt.—Set the whole in a warm place to diffolve, and the ink is made.

823 Oil of arfenic. XV. *With Regulus of Arfenic.* This fubftance is foluble in all acids; but the nature of the compounds formed by fuch an union is little known. If half a pound of regulus is diftilled with one pound of corrofive fublimate, a thin fmoking liquor and a butyraceous fubftance will be obtained, as in making the fmoking liquor of Libavius. By repeated rectifications, this butter may be almoft all converted into fpirit. If equal parts of the arfenic and fublimate are ufed, a ponderous black oil comes over along with the fpirit, which cannot be mixed with it. By rectification in a clean retort they will become clear, but ftill will not incorporate. If they are now returned upon the red mafs remaining in the firft retort, and again diftilled, a much more ponderous oil than the former will be obtained.

824 Marine ether. XVI. *With Inflammable Subftances.* The acid of fea-falt is very little difpofed to contract any union with the phlogifton, while in a liquid ftate; and much lefs fo, even in its moft concentrated ftate, than either the vitriolic or nitrous. Mr Beaumé, however, has found, that a fmall quantity of ether, fimilar to that prepared with the vitriolic and nitrous acids, may be obtained by caufing the fumes of the marine acid unite with thofe of fpirit of wine. Others, and particularly fome German Chemifts, attempted to make this liquor, by employing a marine acid previoufly combined with metallic fubftances, fuch as butter of antimony. The fmoking liquor of Libavius fucceeds beft. If equal parts of this liquor and highly rectified fpirit of wine are diftilled together, a confiderable quantity of true ether is produced; but which, like the vitriolic and nitrous ether, muft be rectified in order to its greater purity. The tin contained in the fmoking liquor is feparated and precipitated in white powder. In this procefs, the acid is probably more difpofed to unite with the fpirit of wine, by having already begun to combine with the inflammable principle of the metal.—For marine ether, Mr Dollfufs recommends to put into a retort four ounces of digeftive falt previoufly well dried and powdered, and two ounces of manganefe; pouring upon this a mixture of five ounces of fpirit of wine and two of oil of vitriol; the firft five ounces and a half of the diftilled liquor being poured back on the refiduum, and the whole afterwards drawn off by a gentle heat. The fpirit of falt thus obtained had a very penetrating agreeable odour, fomewhat like that of nitrous ether; and at firft fwam upon the top of water; but at length mixed with it on being agitated for a long time. Towards the end of the diftillation a little oil was obtained, which did not mix with the water; and by the addition of four ounces more of fpirit of wine, more of the dulcified acid was obtained. With regard to this kind of ether, however, Mr Weftrumb denies that it can be made by any method hitherto known; and infifts, that all the liquids as yet produced under the name of marine ether are in reality dulcified fpirit of falt, and not true ether, which will fwim on the top of water.

825 Attraction for phlogifton. Dr Prieftley has obferved, that the pure marine acid, when reduced to an invifible aerial ftate, has a ftrong affinity with phlogifton; fo that it decompofes many fubftances that contain it, and forms with them an air permanently inflammable. By giving it more time, it will extract phlogifton from dry wood, crufts of bread not burnt, dry flefh; and, what is ftill more extraordinary, from flints. From what has been above related, it appears that the dephlogifticated fpirit of falt has a very ftrong attraction for phlogifton.

Effential oil of mint abforbed the marine acid air pretty faft, and prefently became of a deep brown colour. When taken out of this air, it was of the confiftence of treacle, and funk in water, fmelling differently from what it did before; but ftill the fmell of the mint was predominant. Oil of turpentine was alfo much thickened; and became of a deep brown colour, by being faturated with acid air. Ether abforbed the air very faft; and became firft of a turbid white, and then of a yellow and brown colour. In one night a confiderable quantity of ftrongly inflammable air was produced.

Having once faturated a quantity of ether with acid air,

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air, he admitted bubbles of common air to it, through the quickſilver by which it was confined, and obſerved that white fumes were made in it, at the entrance of every bubble, for a conſiderable time. Having at another time, ſaturated a ſmall quantity of ether with this kind of air, and the phial which contained it happening to be overturned, the whole room was inſtantly filled with a white cloud, which had very much the ſmell of ether, but peculiarly offenſive. Opening the door and window of the room, this light cloud filled a long paſſage and another room. The ether, in the mean time, was ſeemingly all vaniſhed: but, ſometime after, the ſurface of the quickſilver in which the experiment had been made was covered with a very acid liquor, ariſing probably from the moiſture in the atmoſphere, attracted from the acid vapour with which the ether had been impregnated. This ſeems to ſhow, that however much diſpoſed the marine acid may be to unite with phlogiſtic matters when in its aerial ſtate, the attraction it has for them is but very ſlight, and ſtill inferior to what it has for water.

Camphor was preſently reduced into a fluid ſtate by imbibing this acid air; but there ſeemed to be ſomething of a whitiſh ſediment in it. After continuing two days in this ſituation, water was admitted to it, upon which the camphor immediately reſumed its former ſolid ſtate; and to appearance was the ſame ſubſtance that it had been before.

Strong concentrated oil of vitriol, being put to marine acid air, was not at all affected by it in a day and a night. In order to try whether it would not have more power in a condenſed ſtate, it was compreſſed with an additional atmoſphere; but, on taking off this, the air expanded again, and was not in the leaſt diminiſhed. A quantity of ſtrong ſpirit of nitre was alſo put to it without any ſenſible effect. From theſe laſt experiments it appears, that the marine acid is not able

ad 825 to diſlodge the other acids from their union with water.

New acid diſcovered by Mr Homberg.

Beſides the acids already mentioned, Mr Homberg deſcribes an artificial one generated by mixing two ounces and a half of luna cornea, with an ounce and a half of tin calcined alone and without addition, by means of fire. The mixture is to be expoſed to a naked fire in a coated retort, of which two-thirds ought to be left empty; when a browniſh matter, an ounce and a half in weight, will adhere to the neck of the retort. This matter is tin combined with the marine acid, and the reſiduum is ſilver deprived of the ſame acid, which may therefore now be melted together without any loſs. The ſublimate, well powdered and dried, is to be equally divided into two phials, and ſublimed; by repeating which operation two or three times, a volatile ſalt, of an acid nature, very white and tranſparent, is obtained. The reſiduum of theſe ſublimations is always calx of tin.

§ 4. *Of the* Fluor *Acid.*

826 First diſcovered by Mr Margraaf.

This acid was diſcovered ſome time ago by Mr Margraaf, and more fully inveſtigated by Mr Scheele. The experiments by which it was originally produced, and its properties aſcertained, are as follows:

827 How prepared.

I. Two ounces of concentrated vitriolic acid were poured upon an equal quantity of fluor, which had been previouſly pounded in a glaſs mortar, and then put into a retort, to which a receiver was adapted, and the juncture cloſed with grey blotting paper. On the application of heat, the maſs began to effervefce and ſwell, inviſible vapours penetrated every where through the joining of the veſſels, and towards the end of the proceſs white vapours aroſe, which covered all the internal parts of the receiver with a white powder.—The maſs remaining in the retort was as hard as a ſtone, and could not be taken out without breaking the veſſel. The lute was quite corroded and friable.

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II. The proceſs was repeated exactly in the ſame manner, excepting only that a quantity of diſtilled water was put into the receiver. A white ſpot ſoon began to form on the ſurface of the water, juſt in the centre, and immediately under the mouth of the retort. This ſpot continually increaſed, till at laſt it covered the whole ſurface of the water, forming a pretty thick cruſt, which prevented the communication of the water with new vapours that came over. On gently agitating the receiver, the cruſt broke, and fell to the bottom; ſoon after which a new cruſt like the former was produced. At laſt the receiver, and ſoon after the retort alſo, became white in the inſide. The veſſels, when cooled, were found much corroded internally. In the receiver was an acid liquor mixed with much white matter, ſeparable by filtration.

828 Forms a white earthy cruſt with water

III. This white matter when edulcorated and dried, ſhowed itſelf to be ſiliceous earth by the following properties. 1. It was rare, friable, and white. 2. It was not ſenſibly ſoluble in acids. 3. It did not make a tough paſte with water, but was looſe and incoherent after being dried. 4. It diſſolved by boiling in lixivium tartari, and the ſolution in cooling aſſumed a gelatinous conſiſtence. 5. In its pure ſtate it ſuffered no change in the ſtrongeſt heat; but when mixed with alkali, it boiled, frothed up, and formed a glaſs in a melting heat. 6. It diſſolved in borax without ſwelling.

829 Which has the properties of ſiliceous earth.

IV. To determine whether this earth was formed during the proceſs, he poured vitriolic acid upon powdered fluor contained in a cylinder of braſs which was cloſed exactly with a cover, after having ſuſpended over the mixture an iron nail and a bit of charcoal. On opening the veſſel two hours afterwards, he found the nail and charcoal unchanged; but on moiſtening them, he found both covered with a white powder in a ſhort time. This powder had all the properties of ſiliceous earth; and as in the experiment he had made no uſe of glaſs veſſels, he concluded that it did not proceed from the glaſs veſſels as might have been ſuſpected from their being ſo much corroded, but was generated in ſome other way.

830 Scheele's experiment to determine the origin of this earth.

V. Having recompoſed fluor by ſaturating the acid with calcareous earth, he treated the compound in the ſame manner as the natural fluor, with a ſimilar reſult; and repeating the experiment five times over, he conſtantly found the ſiliceous earth and acid diminiſh conſiderably, ſo that at laſt ſcarce any mark of acidity was left. Thence he concluded, that all the fluor acid united itſelf by degrees with the vapours of the water, and thus formed the ſiliceous earth. "It may be objected (ſays Mr Scheele), that the fluor acid is perhaps already united by nature with a fine ſiliceous powder,

831 Artificial fluor yields a ſimilar reſult.

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der, which it volatilizes, and carries over in distillation, but leaves it as soon as it finds water to unite with, just as muriatic acid parts with the regulus of antimony, when butter of antimony is dropped into water. But if this was the case, the fluor acid would leave the whole quantity of siliceous earth thus combined with it in the first distillation, and therefore show no mark of its presence in the following processes. When I put spirit of wine into the receiver instead of water no siliceous earth was produced; but the alcohol became sour. When I put an unctuous oil into the receiver, all the fluor acid penetrated through the crevices of the lute, and neither united with the oil, nor produced a siliceous earth. This happened also when acid of vitriol was put into the receiver. If therefore the siliceous earth was not a product of each distillation, but, being previously contained in the acid, was only deposited from it in consequence of the union of the acid with a third substance, I think the siliceous earth ought equally to appear when alcohol was put into the receiver, with which it unites, as well as with water; but as this does not happen, I conclude that not all the siliceous earth, which is deposited upon the surface of water during the distillation of the fluor acid, was previously dissoved in this acid."

832 Mr Scheele's conclusion that the earth proceeds from an union of the acid with water.

833 Contested by Messrs Boullanger Monnet, &c.

This opinion of Mr Scheele did not meet with general approbation. M. Boullanger endeavoured to show, that the fluor acid is no other than the muriatic intimately combined with some earthy substance; and Mr Monnet maintained that it is the same with that of vitriol volatilized by some extraordinary connection with the fluor; which opinion was also maintained by Doctor Priestley. Mr Scheele contested these opinions, but found much greater difficulty in supporting his own opinions than in overthrowing those of his adversaries. Boullanger insisted that fluor acid precipitates the solutions of silver and quicksilver, producing luna cornea with the former, and mercurius dulcis with the latter. Mr Scheele owns that fluor acid precipitates both these metals, but the precipitate obtained is in very small quantity, and the little that is produced arises only from a small quantity of sea-salt with which the fluor, as well as all other calcareous substances, is generally mixed. The greatest part of the acid, therefore, will not precipitate the solutions of these metals, which it ought to do upon Mr Boulanger's hypothesis. Mr Scheele then proceeds to show a method of separating this small quantity of marine acid from that of fluor. A solution of silver made with nitrous acid is to be precipitated with alkali of tartar, and as much acid of fluor poured upon the edulcorated powder as is sufficient to give an excess of acid; after which the solution is to be filtered. This solution of silver in fluor acid is then to be dropped into that acid we desire to purify, till no more precipitation ensues; after which the acid is filtered through grey paper, and distilled to dryness in a glass retort. The aqueous part comes over first, but is soon followed by fluor acid, which covers the inside of both the vessels, together with the surface of the water in the receiver, with a thick siliceous crust. The acid thus rectified, does not precipitate solution of silver in the least, or otherwise show the smallest sign of muriatic acid.

834 Their opinions shown to be erroneous by Mr Scheele.

835 Fluor acid proved to be different from that of sea-salt.

That the fluor acid is different from that of vitriol Mr Scheele proved by the following experiment. Upon one ounce of pure levigated fluor with alkohol, he poured three ounces of concentrated oil of vitriol, and distilled the mixture in a sand-bath, having previously put 12 ounces of distilled water into the receiver. He then took other three ounces of the same acid diluted with 24 ounces of water, to which he afterwards added lixivium tartari previously weighed, till he attained the exact point of saturation. After the distillation he weighed the remaining lixivium; having kept up such a degree of heat for eight hours as was not sufficient to raise the vitriolic acid. On breaking the retort, and reducing the mass to powder he boiled it in a glass vessel with 24 ounces of water for some minutes; after which he added just as much lixivium tartari as he had found before to be requisite for the saturation of three ounces of the vitriolic acid, and continued the boiling for a few minutes longer. On examining the solution, it was found to contain a vitriolated tartar perfectly neutralized, neither acid nor alkali prevailing in any degree; which showed that no vitriolic had passed into the receiver. The saline matter being then extracted with hot water, the remaining earth was found to weigh 9½ drachms. Two drachms of this dissolved in muriatic acid, excepting only a small quantity of matter which seemed to be fluor undecomposed, and which on being dried weighed only nine grains. Into one part of this solution he poured some acid of sugar, and into another vitriolic acid. The former produced saccharated lime, and the latter gypsum. A third part was evaporated to dryness, and left a deliquescent salt; and the remaining part of the earth burned in a crucible, produced a real quick lime.

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836 And from that of vitriol.

837 Quicklime the basis of fluor.

Thus it appeared that the real basis of fluor is quicklime, and likewise that the fluor acid is different from that of vitriol, as appears farther from the following considerations: 1. Pure fluor acid does not precipitate terra ponderosa, nor solution of lead in nitrous acid. 2. The same acid, when saturated with alkali of tartar, evaporated to dryness, and afterwards melted with powdered charcoal, does not produce any hepar sulphuris.

838 Mistake of Mr Monnet on this subject.

Mr Monnet, in order to support his hypothesis, denies that fluor contains any calcareous earth. In proof of which he adduces the following experiment: Equal quantities of alkali and fluor were melted together, with little or no change on the mineral; for, after having taken away by lixiviation the alkali employed, he dissolved the fluor remaining on the filter in nitrous acid, adding vitriolic acid to the solution; and because he obtained no precipitate, concluded at once, that fluor contains no calcareous earth. Mr Scheele on the contrary affirms, that all solutions of fluor yield a precipitate of gypsum whenever vitriolic acid is added to them. He explains Mr Monnet's failure, by supposing that he had diluted his solution with too great a quantity of water.

839 Wiegleb's experiments on the origin of the siliceous earth

Mr Wiegleb, dissatisfied with the hypothesis of Scheele, as well as others, concerning the fluor acid, began a new set of experiments on the mineral. Having first accurately repeated those made by Mr Scheele, he proceeded to inquire into the origin of the siliceous earth, in the following manner: Having first weighed the retort destined for the experiment in an

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an accurate manner, and found that its weight was two ounces and five drachms, he put into it two ounces of calcined fluor in powder, adding, by means of a glafs tube, 2½ ounces of oil of vitriol. The retort was then placed on the furnace; and a receiver, which when empty weighed two ounces, two drachms, and 30 grains, and now contained two ounces of diftilled water, was luted to it. The diftillation was conducted with all poffible care, and at laft pufhed till the retort grew red hot; but it was found impoffible to prevent a few vapours from penetrating through the lute. Next day the retort, feparated from the receiver, was found to weigh, together with its contents, five ounces, five drachms, and 30 grains; and confequently had loft in weight one ounce, three drachms, and 30 grains, The receiver, which, with the water, had originally weighed four ounces, two drachms, and 30 grains, now weighed five ounces and three drachms, and had therefore gained one ounce and 30 grains. This gain, compared with the lofs of the retort, fhows that the retort loft more by three drachms than the receiver gained; fo that thefe muft have undoubtedly paffed through the luting in form of vapour.

To determine the point in queftion, the empty veffels, with what had been put into them, were accurately weighed; when the weights and lofs upon the whole were found to be as follows.

	oz.	dr.	gr.
The empty retort - - -	2	5	0
Calcined fluor - - -	2	0	0
Oil of vitriol - -	2	4	0
Total weight before diftillation	7	1	0
After it -	5	5	30
Lofs of retort - -	1	3	30
The empty receiver weighed -	2	2	30
The water put into it - -	2	0	0
Total weight before diftillation	4	2	30
Total weight after diftillation -	5	3	0
Gain of receiver -	1	0	30

Deducting this grain of weight in the receiver from the lofs of weight in the retort, we find, that three drachms were wanting on the whole, which muft undoubtedly, as already obferved, have been diffipated in vapour. The retort being now broken, and the dry earth both in its neck and arch feparated as accurately as poffible, it was found to weigh three drachms; the refiduum in the retort weighed three ounces, two drachms, and 40 grains. Now, as the mafs in the retort had originally weighed four ounces and four drachms, it appeared, by deducting the refiduum, to have fuffered, on the whole, a lofs of one ounce, one drachm, and 20 grains. To determine the lofs more accurately, the following calculations were made:

	oz.	dr.	gr.
The white earth feparated from the neck and arch of the retort -	0	3	0
Gain of the receiver - -	1	0	30
Loft in vapour - - - -	0	3	0
Total	1	6	3

Here Mr Wiegleb was furprifed to find, that the matter which came from the retort amounted to more by five drachms ten grains than the mafs in the retort had loft of its original weight; to illuftrate which it was neceffary to weigh the retort and receiver by themfelves. The pieces of the retort now weighed only one ounce feven drachms and 50 grains; whereas, before the procefs, the weight of the retort was two ounces five drachms. It appeared, therefore, that it had loft five drachms ten grains, the very quantity which had been gained by the receiver. This laft had loft nothing of its original weight.

The fluid in the receiver was next diluted with four ounces of diftilled water, and the whole poured out on a filter, in order to feparate the earthy matter with which it was mixed, and frefh water poured upon it to take out all the acid: after which the earth was dried, and found to weigh 57 grains. The clear liquor was then diluted with more diftilled water, and afterwards precipitated with fpirit of fal ammoniac prepared with fixed alkali. A brifk effervefcence took place before any precipitate began to fall, but ceafed foon after the precipitation took place. The whole mixture become gelatinous; and the precipitate, when dry, weighed two drachms. The whole quantity of earth, therefore, obtained in this procefs amounted to five drachms 47 grains, which is forty-feven grains more than the retort had loft in weight. This excefs is, by our author, attributed to part of the acid ftill adhering to it, and to the acceffion of fome moifture from the air; to determine which he heated each of the parcels of earth red hot feparately, and thus reduced them to four drachms 52 grains, which is lefs by 18 grains than the lofs of the retort, and which, he is of opinion, muft have efcaped in the three drachms of vapour.

840 The earthy cruft proceeds from the folution of the glafs diftilling veffels.

From this experiment Mr Wiegleb concludes, that the earth produced in the diftillation of fluor proceeds neither from the fpar nor from a combination of the acid with water, but from the folution of the glafs by the fparry acid. To his opinion alfo Dr Crell accedes. "In diftilling fluor (fays he) with oil of vitriol, I have found the retort as well as the receiver very much corroded. I poured the acid obtained by the procefs into a phial furnifhed with a glafs ftopper, and obferved after fome time confiderable depofition. I then poured the liquor into another phial like the former; and that it might neither on the one hand attack the glafs, nor on the other compofe filiceous earth with the particles of water, according to Mr Scheele's hypothefis, I added highly rectified fpirit of wine. I faw, however, after fome time, another confiderable depofition. This feemed alfo to proceed from the glafs that had been before diffolved, which the acid let fall in confequence of the gradual combination with the fpirit of wine; otherwife we muft fuppofe, what to me appears incredible, that the acid decompofes the fpirit, attracts the water, and forms the earth."

841 Mr Meyer's examination of the fluor acid.

This fingular acid has been ftill further examined by Mr Meyer. He informs us, that, among Mr Scheele's experiments, he was particularly ftruck by one in which no earthy cruft was obtained, after putting fpirit of wine into the receiver. Mr Meyer repeated this experiment, hoping, that when but little fpirit was put into the receiver, he might be able to procure a new kind of ether. An ounce of finely powdered fluor, which had been previoufly heated red hot, was put into a glafs

Fluor acid and its combinations.

glass retort, to which was fitted a receiver containing three ounces of highly rectified French brandy. The distillation was continued for three hours with a gentle heat: when the acid, having made its way through the bottom, put and end to the process. No crust could be perceived on the surface of the spirit: but in the place where it had been in contact with the receiver there was a thin ring of transparent jelly. The same mixture of oil of vitriol and fluor was therefore again put into a retort of very strong glass, and the same spirit put into the receiver. The distillation was conducted two hours with a gentle and afterwards with a stronger, heat. When it was half over, the spirit began to change into a thin jelly; and at the end of the process some firmer pieces were found at the bottom. These were washed with spirit of wine; and in order to obtain the spirit together with the acid in a pure state, it was put into a large retort, and again subjected to distillation. As the retort grew warm, the opal-coloured spirit became clear and swelled, what remained becoming again gelatinous; a good deal of earth remained behind, but did not adhere firmly to the retort, which was smooth in the inside, though full of shallow excoriations. It was also evident, that the glass was actually corroded, and that the earthy matter is not a mere crust adhering to the inside. The jelly being thoroughly edulcorated, as well as the earth that remained in the retort after the rectification, and that which was dissolved in the water precipitated by spirit of sal ammoniac, the whole quantity amounted to two drachms. That which had separated spontaneously was semitransparent. "As this earth (says he) showed the properties of siliceous earth, and the glass, which was so much corroded, consists in great measure of it, the greatest part of it might come from the glass, and the rest of it perhaps be a constituent part of the fluor itself. In order to ascertain this it was necessary to obtain the fluor acid quite free from siliceous earth. I therefore exposed the ley, which I had procured by the precipitation of the earth with sal ammoniac, to a gentle evaporation in a slightly covered glass vessel. The product was one drachm 56 grains of an ammoniacal salt; the glass did not appear to have been attacked. Half a drachm of this salt was sublimed in a small retort, which, towards the end of the operation, was laid on the bare fire. No crust appeared on the surface of the water in the receiver. At the bottom of the retort lay a little flocculent earth of a light grey colour, above which the internal surface was covered with a white pellicle that reflected various colours; and in the neck there was a sublimate. The thin pellicle easily separated in many places from the glass, which was smooth beneath, though not without some small furrows. I poured water both upon the ammoniacal salt and crust; in consequence of which it acquired a very sour taste, and coloured the tincture of turnsole red. The white crust that was left behind undissolved weighed five grains, and melted into a green glass without addition. This was nothing but the glass that had been corroded by the fluor acid; but as this acid can be set loose only by strong heat, it had done no more than corrode the glass, without passing over along with it in the form of vapour, and then deposing it again on the water. For, upon pouring two drachms of oil of vitriol upon half a drachm of this ammoniacal salt

842 How to procure the acid free from siliceous earth.

a little moistened, and placed in a glass retort, a great foam arose, and the thick vapours that ascended covered the water in the receiver with a white crust. A scruple of the salt on solution, left behind a grain of earth, which, as I conjecture, it had taken up during the evaporation in the glass vessel."

To prevent this, our author distilled half an ounce of fluor with an ounce of oil of vitriol for five hours. The crusts were separated from the water; they weighed, after being well washed and dried, eleven grains; they were white and very flocculent; thirty-two grains of siliceous earth were precipitated from the filtered water: the ley was then evaporated in a leaden vessel and yielded 80 grains of salt. As glass vessels were no longer to be trusted, a piece of a gun-barrel furnished with a cover, and terminated by a bent tube, intended to serve instead of the neck of a retort, was afterwards used; and with this apparatus the following experiments were made:

843 Experiments made with an iron distilling vessel.

1. Half a drachm of the newly prepared sal-ammoniac was distilled for two hours with two drachms of oil of vitriol, into a glass receiver containing an ounce of water. No vestige of a crust could be perceived on the water, but some earth was perceived in the receiver, where the vapours having ascended through the tube, came into contact with the wet glass; and here the surface was become sensibly rough. On the addition of volatile alkali, a few flocculi of siliceous earth, a mounting only to one-fourth of a grain, were thrown down out of the water.

2. A drachm of vitriol was added to a drachm and an half of the salt; but a leaden receiver was now used, containing an ounce of water as before. The water acquired an unpleasant smell, but showed no signs of a crust. On the addition of spirit of sal ammoniac, a little grey earth weighing half a grain fell to the bottom.

844 No crust formed by mixing sand, with a salt containing fluor acid.

3. A scruple of this salt, mixed with an equal quantity of white sand in fine powder, and distilled with a drachm and an half of oil of vitriol, into an ounce of water in the leaden receiver, showed no sign of a crust. The water had a putrid smell, and left on the filter two grains and an half of grey earth, which ran under the blow-pipe into a grain of lead. Volatile alkali precipitated five grains of grey earth, which melted on the addition of a little salt of tartar into a black globule, though the blow-pipe alone made no change in it.

845 But a great one by using powdered glass.

4. To 13 grains of the same ammoniacal salt a drachm of oil of vitriol and two scruples of green glass, broken into small pieces, were added. The iron tube had scarce become warm, when a great crust of siliceous earth was perceived on the surface of the water, and the same appearance on the moist sides of the vessel. It did not, however, seem to increase during the remainder of the distillation. A grain and a quarter of earthy matter remained on the filter, consisting partly of white films, which ran under the blow-pipe into a greenish glass.

5. To ascertain this matter still more clearly, a different species of mineral fluor was used, which being distilled with a double quantity of oil of vitriol, and with a drachm of water in the receiver, yielded a thin pellicle of the appearance of lead, but no siliceous crust. Volatile alkali threw down 2¼ grains of grey earth.

Fluor acid and its combinations. earth.—A drachm mixed with the fame quantity of pulverized fand afforded a pellicle of lead interfperfed with a few particles of white cruft, which ran into glafs under the blow-pipe. Volatile alkali precipitated eight grains.—A drachm, mixed with an equal quantity of green glafs reduced to powder, fwelled a good deal, and yielded a thick filiceous cruft.

6. To a drachm of green fluor that had been heated and powdered were added two drachms of oil of vitriol, ftill employing the iron tube. A piece of wet charcoal was alfo fufpended in the infide, a cover fixed on the tube, and the latter was heated for about 15 minutes in a fand-bath. Obferving now that the charcoal was dry, and had no earth upon it, a fcruple of fand in fine powder was added, the charcoal was wetted and replaced, but nothing appeared. Some bits of green glafs were then thrown into the mixture which inftantly foamed up and ran over. The charcoal was not replaced in the tube, nor was it any longer neceffary, as it gained a covering of white powder by being held a very few moments over the orifice.

846 An experiment of Mr Scheele's explained. Mr Scheele, in one of his experiments, obferves, that he obferved the white powder on a piece of charcoal that had been moiftened and fufpended over fluor to which vitriolic acid was added. As this experiment was made in metallic veffels, Mr Meyer conjectures, that the mortar ufed for reducing the fluor to powder was of foft glafs, and that the phenomenon was occafioned by the abrafion of fome particles of glafs.

847 Of the quantity of filiceous earth carried along with fluor acid. 7. To determine whether the acid can carry up much more of the filiceous earth than is fufficient to faturate it, an ounce and an half of pure oil of vitriol was added in a retort of glafs, and three ounces of water put into the receiver. The retort was corroded through in an hour's time, and the cruft on the water weighed ten grains. The liquid being then filtered and divided into two equal parts, one was precipitated with cauftic volatile, and the other with mild fixed vegetable alkali. The former yielded 25 grains of filiceous earth, and the latter 68 grains of a precipitate, which flowed under the blow-pipe, ran into the pores of charcoal, and gave out ftrong vapours of fluor acid. The reafon of this difference fhall be explained when we come to treat of filiceous earth.

848 Violent action of fluor acid upon glafs. 8. To a mixture of half an ounce of fluor and the fame quantity of glafs, in powder, 12 drachms of oil of vitriol were put in a fmall retort, half filled with the mixture. The ingredients acted upon each other fo violently that they rofe up into the neck of the retort; and the operation being intermitted on account of the noxious vapour they emitted, the retort was found next day covered with fafciculated cryftals like hoarfroft.—The experiment being repeated in a more capacious retort, and the mixture thoroughly blended by agitation, it became a thick mafs, and fwelled like dough in fermentation: the bottom of the retort grew very hot, and the filiceous cruft appeared on three ounces of water in the receiver. The diftillation being continued for three hours, 16 grains of filiceous earth were found on the furface, and the precipitate by volatile alkali weighed 56 grains; the retort was much lefs corroded than ufual.

9. Thirty grains of this precipitate, diftilled in a glafs retort with a drachm and an half of oil of vitriol, produced no filiceous earth on the water in the receiver, or that with which the earth was edulcorated. The ley of fluorated volatile alkali was mixed with a folution of chalk in nitrous acid till no more precipitation took place. The mixture was paffed through nitrous acid, and the precipitate edulcorated. It weighed, when dry, two drachms and 36 grains.

10. Two drachms of oil of vitriol being added to a drachm of this precipitate contained in a glafs retort, the precipitate was attacked in the cold, but no cruft appeared; the heat, however, was fcarce applied, when the whole furface of the water was covered, and the fame phenomena exhibited which are produced by the natural fluor.

849 Farther proofs that the earthy crufts proceeds from the glafs veffels. 11. Mr Scheele having obferved that a mixture of fluor as tranfparent as mountain cryftal, and oil of vitriol in a metallic cylinder, produced no appearance of filiceous earth, on a wet fponge fufpended on the infide, at Mr Meyer's requeft he made a new experiment by adding oil of vitriol to portions of fluor of this tranfparent kind placed in two tin cylinders; fome filiceous earth was put into one, and a wet fponge fufpended in both. The next morning the fponge that was fufpended over the cylinder which held the filiceous earth, was covered with the white powder, but no appearance of it was feen on the other. The experiment was repeated by Mr Meyer with the fame refult, but the white cruft did not appear till after a night's ftanding.

12. A drachm of fluor, mixed with two of oil of vitriol, afforded, after a diftillation of two hours, a thin film of lead on the furface of the water in the receiver, but no filiceous earth. The fame mixture was afterwards diftilled with the ufe only of a glafs receiver inftead of a lead one. In the beginning of the diftillation a fmall fpot appeared under the neck of the retort, and the neck itfelf was covered with white powder, but it foon difappeared; and though the empty part of the receiver was corroded, yet no more than half a grain of earth was procured.

These experiments fo clearly point out the origin of the filiceous cruft on the furface of the fluor acid, that its exiftence as a diftinct acid is now univerfally allowed, even by thofe who formerly contended for its being only the vitriolic or fome other acid difguifed.—

850 Mr Wenzel's experiments in a leaden retort. Experiments of a fimilar kind were made by Mr Wenzel, who performed his diftillation in a leaden retort, furnifhed with a glafs receiver. The water was covered with a variegated cruft, and yielded a gelatinous precipitate with fixed alkali. On examining the receiver, he found its internal furface corroded, fo that it appeared as if it had been rubbed with coarfe fand. By fubftituting a leaden receiver, however, inftead of a glafs one, he obtained the acid entirely free from filiceous matter, and containing only a fmall quantity of iron and aluminous earth.

2d 850 Fluor acid procurable by nitrous, muriatic, and phofphoric acid. The fluor acid may alfo be procured by the nitrous, muriatic, and phofphoric acids.—Mr Scheele diftilled one part of the mineral with two of concentrated nitrous acid. One part went over into the receiver along with the fluor acid, and a thick cruft was formed on the water of the receiver. The mafs remaining in the retort was calcareous earth faturated with nitrous acid.

Fluor acid and its combinations.

With an equal quantity of marine acid, that of fluor paſſed over into the receiver with a large quantity of the muriatic; the internal ſurface of the receiver, as well as of the water contained in it, being covered with a white cruſt. The reſiduum was fixed ſal ammoniac.

Phoſphoric acid digeſted with powdered fluor, diſſolved a good deal of it; and on diſtilling this ſolution, the fluor acid went over together with the watery particles of the mixture; the remaining maſs in the retort had the properties of the aſhes of bones.

3d 850 Appearance and properties of fluor acid.

The fluor acid procured in any of theſe ways is not diſtinguiſhable by the ſmell from that of ſea-ſalt: in ſome caſes it acts as muriatic acid, in others like that of tartar; but in moſt caſes it ſhows properties peculiar to itſelf.

4th 850 Combined with fixed alkali.

With fixed alkali the fluor acid forms a gelatinous and almoſt inſipid matter, which refuſes to cryſtallize. By evaporation a ſaline maſs was obtained, which was in weight only the ſixth part of the fixed alkali diſſolved; did not change the colour of ſyrup of violets, but precipitated lime water, and likewiſe the ſolutions of gypſum and Epſom ſalt. With mineral alkali the ſame phenomena were produced as with the vegetable.

851 With volatile alkali.

Volatile alkali with fluor acid formed likewiſe a jelly, which when ſeparated from the liquor appeared to be ſiliceous earth. The clear liquid taſted like vitriolic ammoniac, and ſhot into very ſmall cryſtals, which by ſublimation yielded firſt a volatile alkali, and then a kind of acid ſal ammoniac. By diſtillation with chalk and water, all the volatile alkali quickly came over. Lime water inſtantly threw down a regenerated fluor, which was the caſe alſo with ſolutions of lime in the nitrous and muriatic acids.—Solution of ſilver let fall a powder, which, before the blow-pipe, reſumed its metallic form, the acid being diſſipated, and forming a white ſpot on the charcoal round the reduced ſilver. Solution of quickſilver in nitrous acid was precipitated, and the powder was entirely volatile in the fire; but a ſolution of corroſive ſublimate remained unchanged. Lead was totally precipitated from nitrous acid; and a ſolution of Epſom ſalt was rendered turbid. Oil of vitriol produced a fluor acid by diſtillation, which formed at the ſame time a thick cruſt on the water of the receiver. The regenerated fluor procured either by means of lime water or ſolutions of the earth in acids, was decompoſed by fixed, but not by volatile alkali.

852 With earths.

With lime, magneſia, and earth of alum, this acid became gelatinous. Part of the two laſt were diſſolved.

853 With metal.

Gold was not touched by the fluor acid either alone or mixed with that of nitre. Silver, in its metallic ſtate, underwent no change. Its calx, precipitated by an alkali, was partly diſſolved; but the remainder formed an inſoluble maſs at the bottom Vitriolic acid expelled the fluor acid in its uſual form. Quickſilver was not diſſolved, but its calx precipitated from the nitrous ſolution was partially ſo. The remaining inſoluble part of the calx united with the acid, and formed a white powder, from which the fluor acid was expelled by the vitriolic. The ſame powder formed, by means of the blow-pipe, a yellowiſh glaſs; which, however, evaporated by degrees, leaving a ſmall globule of fixed glaſs behind. Lead was not diſſolved, but the acid formed a ſweet ſolution with its calx; from whence the latter could be precipitated by the acids of vitriol, and ſea-ſalt, as alſo by ſal ammoniac. On digeſting a quantity of acid with calx of lead, which had been previouſly digeſted in the ſame, a ſpontaneous precipitation took place. The precipitate melted eaſily before the blow-pipe, and ran into metal; but part of the glaſs remained fixed in the fire. Copper was partially diſſolved, as appeared by the blue colour aſſumed by the liquid on the addition of volatile alkali. The calx of copper was eaſily ſoluble; and the liquor, though gelatinous, yielded blue cryſtals, partly of a cubic and partly of an oblong form, from which the acid could not be ſeparated but by heat. Iron was violently attacked, and gave out inflammable vapours during the ſolution. The liquor refuſed to cryſtallize; but, by evaporation, congealed into an hard maſs after the moiſture was diſſipated; and from this maſs the fluor acid might be expelled as uſual by oil of vitriol. The ſame effect was alſo produced by heat alone; the acid riſing in vapours, and leaving a red ochre behind. Calx of iron was alſo diſſolved, and the ſolution taſted like alum; but it could not be reduced to cryſtals. Tin, biſmuth, and regulus of cobalt, were not attacked in their metallic ſtate; but the calces of all of them were ſoluble. Regulus of antimony and powdered antimony were not ſenſibly acted upon. Zinc produced the ſame effects as iron, excepting that the ſolution ſeemed more inclined to cryſtallize.

854 Glaſs corroded by this acid, as well as the ſalt formed by its combination with volatile alkali.

The moſt remarkable property of this acid, however, is its readily diſſolving glaſs and carrying it off in the form of vapour. This ſingular property belongs not only to the pure acid, but alſo to the ammoniacal ſalt formed by combining it with the volatile alkali. Mr Wiegleb informs us, that on evaporating to dryneſs, in a cup of Miſnia porcelain, a ſolution of this kind of ammoniac, which by its ſmell ſhowed an exceſs of volatile alkali, the glazing of the inſide was entirely corroded, and the bottom left as rough as a file. During the evaporation the cup was covered with white paper, which when dry appeared full of ſmall cryſtals of an acid taſte, eaſily diſtinguiſhable by the naked eye. Theſe, as well as the ammoniacal ſalt, powerfully attracted the moiſture of the air.

855 It is very difficult to be kept.

This property of the fluor acid renders it extremely difficult to be kept. Mr Meyer informs us, that having kept ſome upwards of a year in a glaſs phial, it corroded the glaſs in many points ſurrounded with concentric circles, depoſiting a powder which adhered to the bottom. He is of opinion that golden veſſels would be moſt proper for keeping this acid, as alſo for making experiments on the fluor itſelf. A phial covered in the inſide with wax and oil has been recommended for the ſame purpoſe.

856 Golden veſſels moſt proper for this purpoſe.

857 Dr Prieſtley's experiments on converting this acid into a kind of air.

This acid, as well as thoſe of vitriol, nitre, and ſea-ſalt, has been exhibited by Dr Prieſtley in an aerial form. Having put ſome pounded ſpar into a phial, and poured oil of vitriol upon it, adopting at the ſame time the uſual apparatus for obtaining air, he obſerved that a permanent cloud was formed by the vapour iſſuing out from the mouth of the tube, which he attributed to the attachment of the acid to the aqueous moiſture of the atmoſphere. The moment that water

came

Sal ſedativus and its combinations.

came in contact with this air, its ſurface became opaque and white by a ſtony film, which retarded the aſcent of the water, till the air inſinuating itſelf through the pores and cracks of the cruſt, the water neceſſarily roſe as the air diminiſhed; and breaking the cruſt, preſented a new ſurface to the air, which was immediately covered with another cruſt. Thus one ſtony incruſtation was formed after another till every particle of the air was united to the water; and the different films being collected and dried, formed a white powdery ſubſtance, generally a little acid to the taſte; but when waſhed in much pure water, perfectly inſipid. The property of corroding glaſs he found to belong to the fluor acid air only when hot. From ſome other experiments he concluded, that the fluor acid air was the ſame with what he had formerly obtained from vitriolic acid: but the experiments made ſince that time by various chemiſts, have now convinced him that it is an acid of a nature entirely different from all others.

2d 857 Method of engraving on glaſs.

By means of the fluor acid, a new art has been diſcovered, viz. that of engraving upon glaſs. For this purpoſe a looking-glaſs plate is to be covered with melted wax or maſtic; and when the coating becomes hard, it is to be engraved upon by a very ſharp-pointed needle or other inſtrument of that kind. A mixture of oil of vitriol and fluor acid are then to be put upon the plate, and the whole covered with an inverted China veſſel, to prevent the evaporation of the fluor acid. In two days the glaſs plate may be cleared of its coating, when all the traces of the needle will be found upon it.

§ 5. *Of the* Sal Sedativus, *or Acid of Borax.*

858 Found in a mineral in Germany, &c.

This is a ſaline ſubſtance of a very ſingular nature, and till lately found no where but in borax itſelf. Its origin in different parts of the world is related under the article Borax: but ſince that article was printed, we have accounts of its being diſcovered in a mineral of a peculiar kind found at Lunenburg near Hartz. This is frequently tranſparent, but ſometimes alſo a little opaque, and ſtrikes fire ſlightly with ſteel. It has hitherto been found only in ſmall cryſtals inveloped in a gypſeous matter. Theſe generally affect the cubical form, though they are ſometimes irregular, and from the truncatures frequently appear to be of different kinds. One of them had fourteen faces, ſix ſmall ſquare planes, and eight hexahedral; though all theſe are modifications of cubes. Mr Weſtrumb analized it with ſome difficulty; but at laſt found that 100 parts of the mineral contained 60 of ſedative ſalt, ten of magneſia, and ten of calcareous earth; of clay and flint five parts, ſometimes ten of iron, though frequently but five. The ſame acid has alſo been diſcovered in Peru, and a little in Hungary from an analyſis of petroleum. This bitumen ariſes from a rock between Pecklenicza and Moſcowina. It ſeems at firſt to be white, but ſoon grows black by expoſure to the air. It was analyſed by profeſſor Winterl, who found it to contain a tranſparent oil in a butyraceous form, and a true ſedative ſalt, united with the oil by means of an exceſs of phlogiſton. The ſedative ſalt was firſt diſcovered by Bechr, and afterwards more accurately deſcribed by Homberg; but its nature was at firſt very much miſunderſtood, being named the *narcotic ſalt of vitriol*, on account of the vitriolic acid uſed in ſeparating it from the borax. From this it is ſeparable either by ſublimation or cryſtallization. The method by ſublimation is that recommended by Homberg.

2d 858 How prepared from borax.

His proceſs conſiſts in mixing green vitriol with borax, diſſolving them in water, filtering the ſolution, and evaporating till a pellicle appears: the liquor is then to be put into a ſmall glaſs alembic, and the ſublimation promoted till only a dry matter remains in the cucurbit. During this operation, the liquor paſſes into the receiver; but the internal ſurface of the capital is covered with a ſaline matter forming very ſmall, thin, laminated cryſtals, very ſhining, and very light. This is the ſedative ſalt. The capital is then to be unluted, and the adhering ſalt ſwept off with a feather; the part of the liquor which paſſed laſt into the receiver, is to be poured on the dry matter in the cucurbit; and a new ſublimation is to be promoted as before, by diſtilling till the matter in the cucurbit is dry. Theſe operations are to be frequently repeated in the ſame manner, till no more ſedative ſalt can be obtained.

To obtain the ſedative ſalt by cryſtallization, borax is to be diſſolved in hot water; and to this ſolution any one of the three mineral acids is to be gradually added, by a little at a time, till the liquor be ſaturated, and even have an exceſs of acid, according to Mr Beaumé's proceſs. The liquor is then to be left in a cold place; and a great number of ſmall, ſhining, laminated cryſtals will be formed; theſe muſt be waſhed with a little very cold water, and drained upon brown paper. The ſedative ſalt obtained by this proceſs is ſomewhat denſer than that obtained by ſublimation; the latter being ſo light that 72 grains are ſufficient to fill a large phial.

859 Fixed in the fire.

Sedative ſalt, though thus capable of being once ſublimed, is not, however, volatile; for it ariſes only by means of the water of its cryſtallization; and when it has once loſt its water by drying, it cannot be raiſed into vapours by the moſt violent fire, but remains fixed, and melts into a vitreous matter like borax itſelf. This glaſs is ſoluble in water; and then becomes ſedative ſalt again. A great quantity of water is required to diſſolve the ſedative ſalt, and much more of cold than of boiling water; whence it is cryſtallizable by cold, as it alſo is by evaporation; a ſingular property, which ſcarce belongs to any other known ſalt.

860 Its properties.

This ſubſtance has not an *acid*, but a ſomewhat bitteriſh, taſte, accompanied with a ſlight impreſſion of coolneſs. It nevertheleſs unites with alkaline ſalts as acids do, and forms with them neutral ſalts. It is ſoluble in ſpirit of wine, to which it communicates the property of burning with a green flame. It makes no change on the blue colour of vegetables, as other acids do. It expels the other acids from their baſes, when diſtilled with a ſtrong heat; though theſe are all capable of expelling it in the cold, the acid of vinegar not excepted.

861 Mr Bourdelin's experiments.

The compoſition of ſedative ſalt is very much unknown, as no means ſufficient for its decompoſition have hitherto been found out. Mr Bourdelin, who made many experiments on this ſalt, found that it was unalterable by treatment with inflammable matters, with ſulphur, with mineral acids diſengaged, or united with metallic ſubſtances, and with ſpirit of wine. He

Sal fedativus and its combinations. could only perceive fome marks of an inflammable matter, and a little marine acid. The former difcovered itfelf by its communicating a fulphureous fmell to the vitriolic acid employed; and the latter by a white precipitate formed in a folution of mercury in the nitrous acid, by the liquor which came over on diftilling the falt with powdered charcoal.

862 Mr Cadet's experiments. Mr Cadet, in the Memoirs of the Royal Academy of Sciences for 1766, has given an account of fome experiments made by him on borax and its acid: from which he infers (1). That the acid contained in borax itfelf is the marine, and not fedative, falt. (2.) That it is the marine, he proves by having made a corrofive fublimate with this acid and *mercurius precipitatus per fe*. That fedative falt does not enter the compofition of borax itfelf, he proves, by the impoffibility of recompofing borax from uniting the fedative falt with foffile alkali. The falt fo produced, he owns, is very like borax, but unfit for the purpofes of foldering metals as borax is. He therefore thinks, that, in the decompofition of borax, the principles of the falt are fomewhat changed, by the addition of that acid which extricates the fedative falt; and that this falt is compofed of the marine acid originally exifting in the borax, of the vitriolic acid employed in the operation, and of a vitrefcible earth. (If this is true, then fedative falt either cannot be procured by any other acid than the vitriolic, or it muft have different properties according to the acid which procures it.) The vitrefcible earth, he fays, is that which feparates from borax during its folution in water, and which abounds more in the unrefined than refined borax, and which he thinks confifts of a calx of copper, having obtained a regulus of copper from it. As he has never been able, however, to compofe borax by the union of thefe ingredients, his experiments are by no means decifive. Mr Beaumé has afferted that it is always produced by rancid oils; but Dr Black thinks his proofs by no means fatisfactory.

Sedative Salt COMBINED,

I. *With Vegetable Alkali.* This falt forms a compound very much refembling borax itfelf in quality; but in what refpects it differs from, or how far it is applicable to, the purpofes of borax, hath not yet been determined.

863 Borax. II. *With Mineral Alkali.* This falt has generally been thought to recompofe borax: and though Mr Cadet has denied this, yet as his experiments are hitherto imperfect and unfupported, we fhall here give the hiftory of that falt, as far as it is yet known.

This falt is prepared in the Eaft Indies. It is faid, that from certain hills in thefe countries there runs a green faline liquor, which is received in pits lined with clay, and fuffered to evaporate with the fun's heat; that a bluifh mud which the liquor brings along with it is frequently ftirred up, and a bituminous matter, which floats upon the furface, taken off; that when the whole is reduced to a thick confiftence, fome melted fat is mixed, the matter covered with vegetable fubftances and a thin coat of clay; and that when the falt has cryftallized, it is feparated from the earth by a fieve. In the fame countries is found native the mineral alkali in confiderable quantity; fometimes tolerably pure, at other times blended with heterogeneous matters of various kinds. This alkali appears to exift in borax, as a Glauber's falt may be formed from a combination of borax with vitriolic acid. For a further account See BORAX.

Borax, when imported from the Eaft Indies, confifts of fmall, yellow, and glutinous cryftals. It is refined, fome fay, by diffolving it in lime-water; others, in alkaline lixivia, or in a lixivium of cauftic alkali; and by others, in alum-water. Refined borax confifts of large eight-fided cryftals, each of which is compofed of fmall, foft, and bitterifh fcales. It has been faid that cryftals of this fize can by no means be obtained by diffolving unrefined borax in common water; that the cryftals obtained in this way are extremely fmall, and differ confiderably from the refined borax of the fhops; infomuch that Cramer calls the large cryftals, not a purified, but an adulterated borax. When diffolved in lime-water, the borax fhoots into larger cryftals; and largeft of all, when the veffel is covered, and a gentle warmth continued during the cryftallization. All this, however, is denied by Dr Black; who fays, that in order to accomplifh the purification, we have only to diffolve the impure borax in hot water; to feparate the impurities by filtration, after which the falt fhoots into the cryftals we commonly fee. During the diffolution, borax appears glutinous, and adheres in part to the bottom of the veffel. From this glutinous quality, peculiar to borax among the falts, it is ufed by dyers for giving a glofs to filks. 864 Refined.

865 Its properties. All acids diffolve borax flowly, and without effervefcence. It precipitates from them moft, but not all, metallic fubftances; along with which a confiderable part of the borax is generally depofited. It does not abforb the marine acid of luna cornea, or of mercury fublimate. It melts upon the furface of the former without uniting, and fuffers the latter to rife unchanged: the borax in both cafes becomes coloured; in the firft, milky with red ftreaks; in the latter, amethyft or purple. Mixed with fal ammoniac, it extricates the volatile alkali, and retains the acid; but mixed with a combination of the marine acid with calcareous earths, it unites with the earth, and extricates the acid. It extricates the acid of nitre without feeming to unite with the alkaline bafis of that falt; nor does it mingle in fufion with the common fixed alkaline falts, the borax flowing diftinct upon their furface. A mixture of borax with twice its weight of tartar, diffolves in one fixth of the quantity of water that would be neceffary to diffolve them feparately: the liquor yields, on infpiffation, a vifcous, tenacious mafs like glue; which refufes to cryftallize, and which deliquates in the air. Borax affords likewife a glutinous compound with the other acids, except the vitriolic; whence this laft is generally preferred for making the fedative falt. It proves moft glutinous with the vegetable, and leaft with the marine. With oils, both expreffed and diftilled, it forms a milky, femi-faponaceous compound. It partially diffolves in fpirit of wine. In conjunction with any acid, it tinges the flame of burning matters green; the precipitate thrown down by it from metallic folutions has this effect. It does not deflagrate with nitre. Fufed with inflammable matters, it yields nothing fulphureous, as thofe falts do which

Acetous acid and its combinations. which contain vitriolic acid. By repeatedly moistening it when considerably heated, it may be entirely sublimed.

Borax retains a good quantity of water in its crystals; by which it melts and swells up in a heat insufficient to vitrify it. It is then spongy and light, like calcined alum; but, on increasing the fire, it flows like water.

§ 6. *Of the* Acetous *Acid and its Combinations.*

867 How procured. This acid is plentifully obtained from all vinous liquors, by a fermentation of a particular kind, (see Fermentation, and Vinegar.) It appears first in the form of an acid liquor, more or less deeply coloured, as the vinegar is more or less pure. By distillation in a common copper-still, with a pewter head and worm, this acid may be separated from many of its oily and impure parts. Distilled vinegar is a purer but not a stronger acid than the vinegar itself; for the acid is originally less volatile than water, though, by certain operations, it becomes more so. After vinegar has been distilled to about $\frac{1}{12}$ of its original bulk, it is still very acid, but thick and black. This matter continues to yield, by distillation, a strong acid spirit, but tainted with an empyreumatic oil. If the distillation is continued, a thick black oil continues to come over; and at last some volatile alkali, as in the distillation of animal substances. The caput mortuum left in the distilling vessel, being calcined in an open fire, and afterwards lixiviated, yields some fixed alkaline salt.

Acetous Acid combined,

868 Sal diureticus. I. *With Vegetable Alkali.* The produce of this combination is the *terra foliata tartari*, or sal diureticus of the shops; but to prepare this salt of a fine white flaky appearance, which is necessary for salt, is a matter of some difficulty. The best method of performing this operation is, after having saturated the alkali with the vinegar, which requires about 15 parts of common distilled vinegar to one of alkali, to evaporate the liquor to dryness; then melt the saline mass which remains with a gentle heat; after which it is to be dissolved in water, then filtered, and again evaporated to dryness. If it is now dissolved in spirit of wine, and the liquid abstracted by distillation, the remaining mass being melted a second time, will, on cooling, have the flaky appearance desired.

A good deal of caution is necessary in the first melting; for the acetous acid is easily dissipable, even when combined with fixed alkali, by fire. It is proper, therefore, that, when the salt is melted, a little should be occasionally taken out, and put into water; and when it readily parts with its blackness to the water, must then be removed from the fire. The salt, when made, has a very strong attraction for water, insomuch that it is not easily preserved, even when put into glass bottles. To keep it from deliquating, Dr Black, therefore, recommends the corks to be covered with some bituminous matter; otherwise they would transmit moisture enough to make the salt deliquate.

869 Acetous acid with fossile alkali. II. *With Fossile Alkali.* This alkali, combined with the acetous acid, forms a salt whose properties are not well known. Dr Lewis affirms, that it is nearly similar to the terra foliata tartari. The author of the Chemical Dictionary, again, maintains it to be quite different: particularly that it crystallizes well, and is not deliquescent in the air; whereas the former cannot be crystallized; and even when obtained in a dry form, unless great care is taken to exclude the air, will presently deliquate.

870 Vegetable ammoniac. III. *With Volatile Alkali.* This combination produces a salt so exceedingly deliquescent, that it cannot be procured in a dry form without the greatest difficulty. In a liquid state, it is well known in medicine, as a sudorific, by the name of *spiritus mindereri.* It may, however, be procured in a dry form, by mixing equal parts of vitriolic sal ammoniac and terra foliata tartari, and subliming the mixture with a very gentle heat. When the salt is once procured, the utmost care is requisite to preserve it from the air.

871 Anomalous salts. IV. *With Earths.* Combinations of this kind are but little known. With the calcareous and argillaceous earths compounds of an astringent nature are formed. According to the author of the Chemical Dictionary, the salt resulting from a combination of vinegar with calcareous earth easily crystallizes, and does not deliquate. With magnesia the acetous acid does not crystallize; but, when inspissated, forms a tough mass, of which two drachms, or two and a half, are a brisk purgative.

872 Distilled verdegris. V. *With Copper.* Upon this metal the acid of vinegar does not act briskly, until it is partly at least calcined. If the copper is previously dissolved in a mineral acid, and then precipitated, the calx will be readily dissolved by the acetous acid. The solution is of a green colour, and beautiful green crystals may be obtained from it. The solution, however, is much more easily effected, by employing verdegris, which is copper already united with a kind of acetous or tartareous acid, and very readily dissolves in vinegar. The crystals obtained by this process are used in painting, under the name of *distilled verdegris.*

The most ready, and in all probability the cheapest, method of preparing the crystals of verdegris is that proposed by Mr Wenzel, by mixing together the solutions of sugar of lead and blue vitriol, when an exchange of bases takes place; the lead being instantly precipitated by the vitriolic acid, and the acetous acid uniting with the copper. From 15 ounces and two drachms of sugar of lead with twelve ounces of blue vitriol, five ounces of the crystals were obtained. The precipitate of lead, though washed several times with water, never lost its green colour. It may either be used, he says, in this state, as a green pigment, or it may be made perfectly white by digestion in dilute nitrous acid.

873 Iron liquor for printing cloth. VI. *With Iron.* Vinegar acts very readily upon iron, and dissolves it into a very brown and almost black liquor, which does not easily crystallize, but, if inspissated, runs per deliquium. This liquor is employed in the printing of linens, calicoes, &c. being found to strike a finer black with madder, and to injure the cloth less, than solutions of iron in the other acids.

874 Lead. VII. *With Lead.* The acetous acid dissolves lead in its metallic state very sparingly; but if the metal is calcined, it acts upon it very strongly. Even after lead is melted into glass, the acetous acid will receive a strong impregnation from it; and hence it is dangerous

to

Acetous acid and its combinations.

to put vinegar into such earthen vessels as are glazed with lead. In the metallic state, only a drachm of lead can be dissolved in eight ounces of distilled vinegar.

875 Cerufs. If lead is exposed to the vapours of warm vinegar, it is corroded into a kind of calx, which is used in great quantities in painting, and is known by the name of *cerufs* or *white lead*. The preparation of this pigment has become a distinct trade, and is practised in some places in Britain where lead is procurable at the lowest price. The process for making cerufs is thus given by the author of the Chemical Dictionary.

"To make cerufs, leaden plates rolled spirally, so that the space of an inch shall be left between each circumvolution, must be placed vertically in earthen pots of a proper size, containing some good vinegar. These leaden rolls ought to be so supported in the pots that they do not touch the vinegar, but that the acid vapour may circulate freely betwixt the circumvolutions. The pots are to be covered, and placed in a bed of dung, or in a sand-bath, by which a gentle heat may be applied. The acid of vinegar being thus reduced into vapour, easily attaches itself to the surface of these plates, penetrates them, and is impregnated with the metal, which it reduces to a beautiful white powder, called *cerufs*. When a sufficient quantity of it is collected on the plates, the rolls are taken out of the pots, and unfolded; the cerufs is then taken off, and they are again rolled up, that the operation may be repeated.

"In this operation, the acid being overcharged with lead, this metal is not properly in a saline state; hence cerufs is not in crystals, nor is soluble in water: but a saline property would render it unfit for painting, in which it is chiefly employed."

876 Observations on the process for cerufs. Though this process may in general be just, yet there are certainly some particulars necessary to make cerufs of a proper colour, which this author has omitted; for though we have carefully treated thin plates of lead in the manner he directs, yet the calx always turned out of a dirty grey colour. It is probable, therefore, that after the lead has been corroded by the steam of vinegar, it may be washed with water slightly impregnated with the vitriolic and nitrous acids.

This preparation is the only white hitherto found fit for painting in oil: but the discovery of another would be very desirable, not only from the faults of cerufs as a paint, but also from its injuring the health of persons employed in its manufacture, by affecting them with a severe colic; which lead, and all its preparations, frequently occasion.

877 Sugar of lead. If distilled vinegar is poured on white lead, it will dissolve it in much greater quantity than either the lead in its metallic form, or any of its calces. This solution filtered and evaporated, shoots into small crystals of an austere sweetish taste called *sugar of lead*. These are used in dyeing, and externally in medicines. They have been even given internally for spitting of blood. This they will very certainly cure; but at the same time they as certainly kill the patient by bringing on other diseases. If these crystals are repeatedly dissolved in fresh acids, and the solutions evaporated, an oily kind of substance will at last be obtained, which can scarcely be dried.

From all the metallic combinations of the acetous acid, it may be recovered in an exceedingly concentrated form, by simple distillation, sugar of lead only excepted. If this substance is distilled in a retort with a strong heat, it hath been said that an inflammable spirit, and not an acid comes over; but this is denied by Dr Black. 878 Inflammable spirit from sugar of lead.

VIII. *With Tin.* The combination of acetous acid with tin is so little known, that many have doubted whether distilled vinegar is capable of dissolving tin or not. 879 Tin.

880 Dr Lewis's experiments concerning the solubility of tin. Dr Lewis observes, "That plates of pure tin put into common vinegar begun in a few hours to be corroded, without the application of heat. By degrees a portion of the metal was taken up by the acid, but did not seem to be perfectly dissolved, the liquor appearing quite opaque and turbid, and depositing great part of the corroded tin to the bottom, in a whitish powder. A part of the tin, if not truly dissolved, is exquisitely divided in the liquor; for, after standing many days and after passing through a filter, so much remained suspended as to give a whitishness and opacity to the fluid. Acid juices of fruits, substituted to the vinegar, exhibited the same phenomena. These experiments are not fully conclusive for the real solubility of tin in these acids, with regard to the purposes for which chemists have wanted such a solution: but they prove what is more important; that tin, or tinned vessels, however pure the tin be, will give a metallic impregnation to light vegetable acids suffered to stand in them for a few hours."

With regard to other metallic substances, neither the degree of attraction which the acetous acid has for them, nor the nature of the compounds formed by the union of it with such substances, are known; only, that as much of the reguline part of antimony is dissolved in this acid as to give it a violent emetic quality. See *Regulus of Antimony*.

Concentration of the *Acetous Acid*.

881 Concentrated vinegar. Common vinegar, as any other weak acid, may be advantageously concentrated by frost; as also may its spirit or the distilled vinegar of the shops: but as the cold, in this country, is seldom or never so intense as to freeze vinegar, this method of concentration cannot be made use of here. If distilled vinegar be set in a water-bath, the most aqueous part will arise, and leave the more concentrated acid behind. This method, however, is tedious, and no great degree of concentration can be produced, even when the operation is carried to its utmost length. A much more concentrated acid may be obtained by distilling in a retort the crystals of copper, mentioned (n° 872) under the name of *distilled verdegris*. A very strong acid may thus be obtained, which has a very pungent smell, almost as suffocating as volatile sulphureous acid. The Count de Lauraguais discovered that this spirit, if heated in a wide-mouthed pan, would take fire on the contact of flaming substances, and burn entirely away, like spirit of wine, without any residuum. The same nobleman also observed, that this spirit, when well concentrated, easily crystallizes without addition. 882 Salt of vinegar.

This

Acetous acid and its combinations. This may seem to be the most proper method of obtaining the acetous acid in its greatest degree of strength and purity: but as the process requires a very strong heat to be used towards the end of the operation, it is probable that part of the acetous acid may be by that means entirely decomposed. It would seem preferable, therefore, to decompose pure terra foliata tartari by means of the vitriolic acid, in the same manner as nitre or sea-salt are decomposed for obtaining their acids. In this case, indeed, the acetous acid might be a little mixed with the vitriolic; but that could easily be separated by a second distillation. A still better method of preparing the acid seems to be by distilling sugar of lead with oil of vitriol. The proportion used by M. Lorenzen of Copenhagen, is three ounces of vitriolic acid to eight of the sugar of lead. Mr Dollfuss recommends two parts of sugar of lead to one of vitriolic acid.

883 Dr Priestley's experiments. Dr Priestley, who gives us several experiments on the vegetable acid when reduced to the form of air, mentions his being easily able to expel it from some exceedingly strong concentrated vinegar, by means of heat alone. This seems somewhat contrary to the count de Lauraguais's observation of the disposition of the *spirit of verdegris*, as it is commonly called, to crystallize: but a still greater difference is, that the vegetable acid air extinguished a candle, when according to the Count's observation, it ought to have been inflammable. The most curious property observed by Dr Priestley is, that the vegetable acid air being imbibed by oil olive, the oil was rendered less viscid, and clearer, *almost like an essential oil*. This is an useful hint; and, if pursued, might lead to important discoveries.

Acetous acid combined with *Inflammable Matter*.

884 Vegetable ether. The only method yet known, of combining acetous acid with the principle of inflammability, is by mixing together equal parts of the strongly concentrated acid called *spirit of verdegris*, and spirit of wine. The result is, a new kind of *ether*, similar to the vitriolic, nitrous, and marine. This ether, however, retains some of the acidity and peculiar smell of the vinegar. By rectification with fixed alkali, it may be freed from this acidity, and then smells more like true ether, but still retaining something of the smell, not of the acid, but the inflammable part of the vinegar.

In this process a greater quantity of ether is obtained than by employing the vitriolic acid: which shows that the vegetable acid is essentially fitter to produce ether than the vitriolic. For making the acetous ether readily, Mr Dollfuss recommends eight ounces of sugar of lead dried by a very gentle heat, until it loses the water of crystallization, when it will weigh five ounces and six drachms. It is then to be put into a glass retort and a mixture of five ounces of vitriolic acid, with eight of spirit of wine, poured upon it, and the whole distilled with a very gentle fire. The first ounce that passes over will be dulcified acetous acid, the next almost all ether, and the third ether in its purest state.

An ether may also be obtained from vinegar of wood. To make it, the most concentrated acid of this kind is to be made use of. For this purpose an empyreumatic acid must first be distilled from beech-wood, and then rectified by a second distillation. Three pounds of this require for their saturation five ounces of purified alkali, which by evaporation and fusion affords three ounces and a quarter of terra foliata tartari. From this, one ounce six drachms of concentrated acid are obtained; and this, on being mixed with an equal quantity of alcohol, yields two ounces one drachm and a half of genuine ether. Acid of tartar and its combinations

§ 7. *Of the Acid of Tartar*.

885 Tartar. TARTAR is a substance thrown off from wine, after it is put into casks to depurate. The more tartar that is separated, the more smooth and palatable the wine is. This substance forms a thick hard crust on the sides of the casks: and, as part of the fine dregs of the wine adhere to it, the tartar of the white wines is of a greyish white colour, called *white tartar*; and that of red wine has a red colour, and is called *red tartar*.

886 Cream of tartar. When separated from the casks on which it is formed, tartar is mixed with much heterogeneous matter; from which, for the purposes of medicine and chemistry, it requires to be purified. This purification is performed at Montpelier; and consists first in boiling the tartar in water, filtrating the solution, and allowing the salt to crystallize, which it very soon does; as tartar requires nearly twenty times its weight of water to dissolve it.

The crystals of tartar obtained by this operation are far from being perfectly pure; and therefore they are again boiled in water, with an addition of clay, which absorbs the colouring matter; and thus, on a second crystallization, a very pure and white salt is obtained. These crystals are called *cream*, or *crystals of tartar*; and are commonly sold under these names.

Dr Black observes, that in the purification of tartar, it is necessary to add some earthy substances, in order to absorb or carry down the colour. Macquer thinks that these substances unite in part with the tartar, and render it more soluble, but they have little disposition to unite with acids; they are the purer kinds of clay, and promote the complete deposition of its impurities; so that in the management of wines it is necessary to add certain powdery substances which have some weight, and fall to the bottom readily; and which, in falling, carry down a number of particles that would otherwise float in the liquor for a long time, being so light that they could hardly be made to subside; but the particles of clay adhering to them increase their gravity; and probably it answers the same purpose in the refinement of tartar.

To obtain the pure Acid of *Tartar*.

887 Scheele's analysis of cream of tartar. For a long time the cream or crystals of tartar were considered as the purest acid which could be obtained from this substance; but, in the year 1770, an analysis of tartar was published in the Swedish transactions, by Mr Scheele. His method of decomposing the salt was, to dissolve it in a sufficient quantity of boiling water, then to add chalk in fine powder till the effervescence ceased. A copious precipitation ensued; and the remaining liquor being evaporated;

Acid of tartar and its combinations.

porated, afforded a soluble tartar. This proved that cream of tartar is not, as was commonly supposed, an acid of a peculiar kind, joined with a great deal of earthy impurities; but really a compound salt, containing an alkali joined with an acid; and that the alkali produced from burnt tartar is not generated in the fire, but pre-existent in the salt.

The whole sediment contained in this experiment, is the calcareous earth combined with the acid of tartar, which may justly be called *selenites tartareus*. If some diluted vitriolic acid is poured upon this selenites tartareus, the vitriolic acid expels the acid of tartar, forming a true selenite with the earth, while the liquor contains the pure acid of tartar. By inspissation this acid may be made stronger, and even formed into small white crystals, which do not deliquate in the air. A particular species of tartar extracted from sorrel hath

888 Essential salt of lemon. been sold for taking spots out of clothes, under the name of *essential salt of lemons*, and which is now discovered to be the same with the acid of sugar.

This experiment was soon after confirmed by Dr Black; who farther observed, that if quicklime was used instead of chalk, the whole acid would be absorbed by the lime, and the remaining liquor, instead of being a solution of soluble tartar, would be a caustic lixivium. The most ready method, however, of procuring the pure acid of tartar seems to be that recommended by Mr Schiller in the Chemical Annals for 1787. One pound of cream of tartar is to be boiled in five or six pounds of water, and a quartar of a pound of oil of vitriol added by little and little, by which means a perfect solution will be obtained. By continuing the boiling, all the vitriolated tartar is precipitated. When the liquor is evaporated to one half, it must be filtered; and if, on the renewal of the boiling, any thing farther is precipitated, the filtration is to be repeated. The clear liquor is then to be reduced to the consistence of a syrup, and set in a temperate, or rather a warm place, when very fine crystals will be formed, and as much acid obtained as is equal in weight to half the cream of tartar employed. If too small a quantity of vitriolic acid has been employed, the undecomposed cream of tartar falls along with the vitriolated tartar.

Acid of Tartar COMBINED,

889 Soluble tartar. I. *With Vegtable Alkali.* If the pure acid of tartar be combined with this alkali to the point of saturation, a neutral salt is produced, which deliquates in the air, and is not easily crystallized, unless the liquor be kept warm, and likewise be somewhat alkaline. This salt, called *soluble tartar*, is used in medicine as a purgative; but as its deliquescence does not admit of its being kept in a crystalline form, it is always sold in powder. Hence those who prepare soluble tartar, take no further trouble than merely to rub one part of fixed alkaline salt with three of cream of tartar, which renders the compound sufficiently neutral, and answers all the purposes of medicine. Dr Black informs us, that in medical prescriptions, where soluble tartar is ordered as a purgative along with a decoction of tamarinds, the acid of the latter will decompose the soluble tartar, and thus the prescription may perhaps be rendered ineffectual. The saline mixture used in fevers is nothing but a tartarus solubilis in solution.

According to Mr Scheele, cream of tartar may be recomposed from the pure acid and alkali in the following manner: "Upon fixed vegetable alkali pour a solution of the acid of tartar. Continue this till the effervescence is over; the fluid will then be transparent; but if more of the acid is added, it will become turbid and white, and small crystals like white sand will be formed in it. These crystals are a perfect cream of tartar. 890 Regenerated cream of tartar.

Upon these principles, another method of decomposing cream of tartar might be tried; namely, adding to it as much oil of vitriol as would saturate the alkali, then dissolving and crystallizing the salt: but, by this method, there would be danger of the acid being adulterated with vitriolic tartar.

891 Siegnette's or Rochelle salt. II. *With Fossile Alkali.* The salt produced from an union of cream of tartar with fossile alkali, has been long known under the names of *Siegnette's salt, sal Rupellensis*, or *Rochelle salt*; but as the cream of tartar is now discovered to be not a pure acid, but adulterated with a portion of soluble tartar, possibly some differences might be observed if the pure acid was used.

This salt was first invented and brought into vogue by one Seignette, an apothecary at Rochelle, who kept the composition a secret as long as he could. Messrs Boylduc and Geoffroy afterwards discovered and published its composition.

To prepare this salt, crystals of mineral alkali are to be dissolved in hot water, and powdered cream of tartar thrown in as long as any effervescence arises. For the better crystallization of the salt, the alkali ought to prevail. The liquor must then be filtered and evaporated, and very fine large crystals may be obtained by cold, each of which is the half of a polygonous prism cut in the direction of its axis. This section, which forms a face much larger than the rest, is, like them, a regular rectangle, distinguishable from the others, not only by its breadth, but also by two distinct diagonal lines which intersect each other in the middle. The following method of preparing Siegnette's salt, recommended by Mr Scheele, seems preferable to any other on account of its ease and cheapness. Thirty six ounces of crystals of tartar are to be saturated with potash, and eleven ounces of common salt dissolved in the ley. When it is grown cold, and the vitriolated tartar has subsided to the bottom, it is filtered and evaporated till a pellicle appears; the two first crystallizations yield a fine Seignette's salt; the third contains some digestive salt; and the fourth is entirely composed of it. The reason of this formation of Seignette's salt is, that the vegetable alkali has a greater attraction for acids than the mineral, and therefore decomposes the sea-salt, whose basis is then at liberty to combine with the acid of tartar; while the stronger marine acid takes the vegetable alkali.—A salt of the same kind will be produced by adding Glauber's salt instead of common sea-salt.

892 Cream of tartar. III. *With Volatile Alkali.* With regard to this combination, all we know as yet is, that if the alkali is over-saturated with acid, a cream of tartar, almost as difficult of solution as that of fixed alkali, will be obtained. When the saturation has been pretty exact, a beautiful salt, composed of four sided pyramids, and which does not deliquate in the air, is produced. It is instantly decompounded, and emits a pungent volatile smell on being mixed with fixed alkali.

IV.

Acid of tartar and its combinations.

IV. *With Earths.* All that is as yet known concerning theſe combinations, is, that with the calcareous earth a compound not eaſily ſoluble in water is formed. The other properties of this ſubſtance, and the nature of combinations of tartareous acid with other

893 Selenites tartareous. earths, are entirely unknown.

894 A fine green colour. V. *With Copper.* In its metallic ſtate, cream of tartar acts but weakly on the metal, but diſſolves verdegris much more prfectly than diſtilled vinegar can. The ſolution of cream of tartar, being evaporated, does not cryſtallize, but runs into a gummy kind of matter; which, however, does not attract the moiſture of the air. It readily diſſolves in water, and makes a beautiful bluiſh green on paper, which has the property of always ſhining, as if covered with varniſh. The effects of the pure acid on this metal have not yet been tried.

895 Chalybeated tartar. VI. *With Iron.* The effects of a combination of iron with the pure acid have not hitherto been tried. Cream of tartar diſſolves this metal into a green liquor, which being evaporated runs *per deliquium.* It has been attempted to ſubſtitute a ſolution of this kind to the liquor uſed in printing calicoes formed of iron and ſour beer; but this gave a very dull browniſh colour with madder. Poſſibly, if the pure acid was uſed, the colour might be improved. In medicine, a combination of cream of tartar with iron is uſed, and probably may be an uſeful chalybeate.

VII. *With Regulus of Antimony.* See Sect. III.

§ 8. *Of the Acid of* Sugar.

896 Saccharine acid. That ſugar contains an acid, which on diſtillation by a ſtrong fire ariſes in a liquid form, in common with that of moſt other vegetable ſubſtances, has been generally known; but how to obtain this acid in a concrete form, and to appearance as pure and cryſtallizable as the acid of tartar, we were entirely ignorant, till the appearance of a treatiſe intitled, *Diſſertatio Chemica, de acido Sacchari, auctore* Johanne Afzelio Arvidſſon, 4to, *Upſaliæ.*

Of the method of procuring, and the properties of, this new acid, we have the following account in the Edinburgh Medical Commentaries, vol. iv.

" 1. To an ounce of the fineſt white ſugar in powder, in a tubulated retort, add three ounces of ſtrong ſpirit of nitre.

" 2. The ſolution being finiſhed, and the phlogiſton of the ſpirit of nitre moſtly exhaled, let a receiver be properly fitted to the retort and luted, and the liquor then made to boil gently.

" 3. When the ſolution has obtained a browniſh colour, add three ounces more of ſpirit of nitre, and let the ebullition be continued till the fumes of the acid are almoſt gone.

897 Chryſtals of ſaccharine acid. " 4. The liquor being at length emptied in a *larger* veſſel, and expoſed to a proper degree of cold, quadrangular priſmatic cryſtals are obſerved to form; which being collected, and dried on ſoft paper, are found to weigh about 109 grains.

" 5. The remaining liquor being again boiled in the ſame retort, with two ounces of freſh ſpirit of nitre, till the red vapours begin to diſappear, and being then in the ſame manner expoſed to cryſtallize, about 43 grains of ſaline ſpiculæ are obtained.

" 6. To the liquid that ſtill remains, about two ounces more of ſpirit of nitre being added, and afterwards the whole being, *both by boiling and evaporation,* reduced to a dry maſs, a brown, ſaline, gelatinous kind of ſubſtance is produced, which, when thoroughly dry, is found to weigh about half a drachm. Acid of ſugar and its combinations.

" In the ſame manner, a ſimilar acid, we are told, may be obtained from different ſaccharine ſubſtances, as *gum-arabic, honey, &c.*; but from none in ſuch quantities, or ſo pure, as from fine ſugar."

898 Preſumption of its expelling the vitriolic acid. This ſalt poſſeſſes ſome very ſingular properties, of which what appears to us the moſt remarkable, and which we cannot help reading with ſome degree of doubt, is, that it produces an effervefcence on being added to ſuch *alkaline, earthy, or metallic ſubſtances, as contain the vitriolic acid.* From this we ſhould be apt to think, that this acid was capable of diſlodging even the vitriolic acid from its baſis.

Acid of ſugar, being diſtilled in a retort, gives over about $\frac{3}{10}$ of its weight of water. By an intenſe heat it melts, and is partly ſublimed; leaving in the retort a dark grey maſs, of about the fifth part of the weight of the cryſtals made uſe of. The ſublimed ſalt eaſily recovers the cryſtalline form, and ſeems to have undergone no further change by ſublimation than being rendered more pure. During the diſtillation a great quantity of elaſtic vapour ruſhes out (about 100 cubic inches from half an ounce of the cryſtals), which, from the diſtilled liquor's precipitating lime-water, we may judge to be fixed air. In a ſecond ſublimation, white fumes are ſent over, which, when cold, appear to be an acid, glaſſy-coloured liquor, but cannot be again cryſtallized. " Such parts of the ſalts as adhere to the ſides and necks of the veſſels do not appear to be in the leaſt changed in the proceſs." On a third ſublimation, theſe parts produced ſuch elaſtic vapours as burſt the receiver.

899 Great acid power. This ſingular ſalt has a conſiderable acid power; twenty grains of it giving a very conſiderable degree of acidity to a large tankard of water. It diſſolves in an equal weight of diſtilled water, but concretes on the liquor's growing cool. It is alſo ſoluble in ſpirit of wine; 100 parts of boiling ſpirit of wine diſſolving 56 of the ſaccharine cryſtals, but no more than 40 when cold. The ſolution in ſpirit of wine ſoon becomes turbid; and depoſites a mucous ſediment, in quantity about $\frac{1}{10}$ of the acid made uſe of. When cold, irregular ſcaly cryſtals are formed, which when dry are perfectly white.

With vegetable alkali, the acid of ſugar can ſcarcely be formed into cryſtals, unleſs either the alkali or acid predominate. With mineral alkali, a ſalt very difficult of ſolution is formed. The quantity of volatile

900 Incredible quantity of volatile alkali ſaturated by it. alkali ſaturated by this acid is incredible. " Six parts of a pure volatile alkali may be ſaturated with one of the acid of ſugar. The produce is a quadrangular priſmatic ſalt. With lime this acid unites ſo ſtrongly, as to be ſeparable by no other means than a ſtrong heat. What kind of a ſalt reſults from this combination we are not told; but the author is of opinion, that this ſhows the uſe of lime in the purification of ſugar, in order to abſorb the ſuperfluous acid. Being ſaturated with ſome of the *terra ponderoſa,* the acid of ſugar immediately depoſits a quantity of pellucid angular cryſtals, ſcarcely ſoluble in water. With magne-

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Acid of sugar and its combinations.

sia the salt appears in form of a white powder, soluble neither in water nor spirit of wine, unless the acid prevails. It has a stronger affinity with magnesia than any of the alkaline salts. With earth of alum, no crystals are obtained; but a yellow pellucid mass, of a sweetish and somewhat astringent taste; which, in a moist air, liquefies, and increases two-thirds in weight.

901 Its effects on metals.

This acid acts upon all metals, gold, silver, platina, and quicksilver, not excepted, if they have been previously dissolved in an acid, and then precipitated. Iron in its metallic state is dissolved in very large quantity by the saccharine acid; 45 parts of iron being soluble in 55 of acid. By evaporation, the liquor shoots into yellow prismatic crystals, which are easily soluble in water. With cobalt, a quantity of yellow-coloured crystals are obtained, which being dissolved in water, and sea-salt added to the solution, form a sympathetic ink. The elective attractions of this singular acid are, first, lime, than the *terra ponderosa*, magnesia, vegetable alkali mineral alkali, and

902 Saccharine ether.

lastly clays. With spirit of wine an ether was obtained which cannot easily be set on fire unless previously heated, and burns with a blue instead of a white flame.

903 Whether this acid is produced from the nitrous.

Towards the conclusion of his dissertation the author observes, that some may imagine that the acid of nitre made use of in these experiments, may have a considerable share in the production of what he has termed *acid of sugar*. But though he acknowledges that this acid cannot in any way be obtained but by the assistance of spirit of nitre, he is thoroughly convinced that it does not, in any degree, enter into its composition.

What occurs to us on this subject is, that if the acid really pre-exists in the sugar, it must give some tokens of its existence by mixing the sugar with other substances besides spirit of nitre. The author himself thinks that lime acts upon the acid part of the sugar: from whence we are apt to conclude, that by mixing lime, in a certain proportion, with sugar, a compound should be obtained somewhat similar to what was formed by a direct combination of lime with the pure acid. In this case, we might conclude that the nitrous acid produces this salt, by combining with the inflammable part of the sugar, becoming thereby volatile, and flying entirely off, so as to leave the acid of the sugar pure. In the distillation of dulcified spirit of nitre, however, we have an instance of the nitrous acid itself being very much altered. This must therefore suggest a doubt that the acid salt obtained in the present case is only the nitrous acid deprived of its phlogiston, and united with some earthy particles.

In a treatise lately published by Mr Rigby, however, we are informed that sugar itself may be recomposed by uniting the acid of sugar with phlogiston; which assertion, if well founded, undoubtedly decides

2d 903 The same with the acid of sorrel.

the dispute in favour of the saccharine acid being originally contained in the sugar. Late experiments have determined it to be the same with that of sorrel; for which, as well as many other valuable acquisitions, the science of chemistry is indebted to Mr Scheele. Having dissolved as much acid of sugar in cold water as the liquor could take up, he added to this solution some lixivium of tartar drop by drop, waiting a little after each drop, and found the mixture, during the effervescence, full of small crystals, which were genuine salt of wood-sorrel. M. Klaproth having precipitated a nitrous solution of quicksilver with salt of wood-sorrel, perfectly neutralized by vegetable alkali, obtained a white precipitate; which, when edulcorated and dried, and gently heated in a tea-spoon, fulminated with a noise not inferior to that of fulminating gold. Acid of sugar perfectly neutralized with vegetable alkali, afforded the same precipitate, and fulminated in the same manner.

Acid of phosphorus and its combinations.

3d 903 Fulminating quicksilver.

§ 9. *Of the Acid of* Phosphorus.

904 Phosphoric acid.

This acid was first discovered by Homberg in urine; afterwards by Margraaf in mustard and cruciferous plants: M. Bochante discovered it in wheat; and lastly, M. Hassenfratz has traced it in the mineral kingdom with great attention.—He has found that phosphorated iron is contained in all the Prussian blues, when not purified; but that this acid is produced by the coals employed in the process, and is no constituent part of the tinging matter. According to him it occurs almost universally in the minerals of iron which are found in the slimy strata of the earth, as well as those which are undoubtedly modern, whether primary or secondary; unless the iron be so far of a metallic nature as to be attracted by the magnet, or very near that state. It is afforded by the ochry strata, and those which contain hæmatites as well as the slimy kind. Into these it is supposed to have come by the decomposition of vegetables; and to investigate this matter he examined the hibiscus palustris, solidago, virga aurea, antirrhinum, lunaria, solanum nigrum, vulgatum, stachys palustris, artemisia Zeylandica, ruta graveolens, lycopus Europeus, carex acuta; vinca major, nepeta Pannonica, and noa Abyssina. All these plants afforded the acid of wood-sorrel and the phosphoric acid. The quantity of the former varied from two ounces to two drachms 18 grains of acid salt containing some calcareous earth, to two drachms 24 grains in a pound of each plant; the quantity of calcareous phosphoric salt being from one ounce six drachms 48 grains to one drachm 12 grains.—M. Hassenfratz also observes, that the phosphoric acid is procurable from all sorts of iron; though in some it seems to proceed from that contained in the earth, and in others from the coals employed in the reduction.

The phosphoric acid is also found by Dr Marquart to be contained in the gastric juice of animals. One pound four ounces of the gastric juice of oxen gave 10 grains of a lymphatic matter, exactly like the blood in its qualities; 16 grains and six-sevenths of phosphoric acid, which with a blow-pipe was changed into a very pure and deliquescent glass of phosphorus; five grains of phosphorated lime, two grains of resin, 14 grains of sal ammoniac, 29 grains of common salt, a very small quantity of an extract whose nature was difficult to ascertain; one pound three ounces six drachms and $67\frac{1}{7}$ grains of water; so that the solid contents were only 166th part of the bulk.

In sheep, the quantity of gastric juice was about eight ounces in quantity, of a deeper and brighter green

Acid of phosphorus and its combinations.

green than that of oxen or calves; but affording the same ingredients, though in a different proportion; though no other acid than that of phosphorus could be discovered. It was also more disposed to putrefaction. Calves furnished from four to six ounces of gastric juice, which contained very little lymph, but afforded some quantity of dry jelly, though the whole was not equal to the proper proportion of lymph. The phosphorated lime was in the usual quantity, but the disengaged phosphoric acid in a very small proportion. The lacteal acid was found in great quantity; to which, along with that of phosphorus, our author supposes the property of curdling the milk in the animal's stomach to be owing.

The phosphoric acid has also been found in very large quantity in the calcareous stones of Andalusia; and Mr Klaproth has found the same combined with calcareous earth in a kind of beryl, crystallized in hexahedral prisms, called by M. Verner *apatit*.—Formerly the best method of obtaining it was from urine, where it is contained in very considerable quantity in combination with the volatile alkali, and forming a salt called the *microcosmic*, or *essential salt of urine*.

905
Microcosmic salt, how procured.

To procure this, a large quantity of urine is to be evaporated to the consistence of a thin syrup; which, being set in a cold place, will yield, in three or four weeks, foul brown-coloured crystals, which are the microcosmic salt, mixed with the marine, and other salts of urine. These crystals are to be dissolved in hot water; the solution filtered whilst it continues hot, and set to crystallize again; and the solution, filtration, and crystallization, repeated till the salt becomes pure and white. In all the crystallizations the microcosmic salt shoots first, and is easily distinguished and separated from the others. If the urine which remains after the first crystallization be further evaporated, and again set in the cold, it will yield more crystals; but browner and more impure than the former; and therefore requiring to be purified by themselves. From 20 gallons of urine may be obtained four ounces of pure salt; a considerable part being still left in the residuum.

In these operations the heat ought to be gentle, and the vessels either of glass or compact stone-ware. Urine being evaporated in a copper vessel, afforded only a green solution of that metal.

906
Mr Margraaf's experiments.

Concerning the nature of the microcosmic salt obtained by the above process, Mr Margraaf gives the following account in the Berlin memoirs for 1746.

"Sixteen ounces of the salt, distilled in a glass retort, in a heat gradually raised, gave over eight ounces of a volatile urinous spirit, resembling that made from sal ammoniac by quicklime. The residuum was a porous brittle mass, weighing eight ounces. This, urged with a stronger fire in a crucible, bubbled and frothed much, and at length sunk down into the appearance of glass, without seeming to suffer any further diminution of its weight in the most vehement heat.

The vitreous matter dissolved in twice or thrice its quantity of water, into a clear, transparent, acid liquor, somewhat thick, not ill resembling in consistence concentrated oil of vitriol. This liquor totally corroded zinc into a white powder, which, being diluted with water, appeared in great part to dissolve, fixed alkalies occasioning a plentiful precipitation. It acted powerfully upon iron, with some effervescence; and changed the metal into a kind of muddy substance inclining to bluish, in part soluble in water like the preceding. It dissolved likewise a portion of regulus of antimony, and extracted a red tincture from cobalt. On lead and tin it had very little action. Copper it corroded but slightly. On bismuth, silver, and gold, it had no effect at all, either by strong digestion, or a boiling heat. Nor did the adding of a considerable portion of nitrous acid enable it to act upon gold.

"The vitreous salt in its dry form, melted with metallic bodies with a strong fire, acts upon them more powerfully. In each of the following experiments, two drachms of the salt were taken to two scruples of the metal reduced to small parts. (1.) Gold communicated a purple colour to the vitreous salt; on weighing the metal, however, its diminution was not considerable. (2.) Silver lost four grains, or $\frac{1}{10}$; and rendered the salt yellowish, and moderately opaque. (3.) Copper lost only two grains, or $\frac{1}{20}$, though the salt was tinged of a deep green colour. It seemed as if a portion of the salt had been retained by the metal, which, after the fusion, was found to be whiter and more brittle than before. (4.) During the fusion with iron, flashes like lightning were continually thrown out; a phosphorus being generated from the combination of the acid with the inflammable principle of the iron. Great part of the mixture rises up in froth; which, when cold, appears a vitreous scoria, covered on the surface with a kind of metallic skin, which, on being rubbed, changes its green colour to a yellowish. The rest of the iron remains at the bottom of the crucible, half melted, half vitrified, and spongy. (5.) Tin lost 18 grains, or nearly one-half its weight, and rendered the salt whitish; the remaining metal being at the same time remarkably changed. It was all over leafy and brilliant, very brittle, internally like zinc. Laid on burning coals, it first began to melt, then burnt like zinc, or phosphorus. (6.) Lead lost 16 grains, and gave the same whitish colour to the scoriæ that tin does. The remaining lead was in like manner inflammable, but burnt less vehemently than the tin; from which it differed also in retaining its malleability. (7.) Mercury precipitated from aquafortis, and well edulcorated, being treated with the salt in a glass retort, with a fire raised to the utmost, only 12 grains of mercury sublimed; 28 remaining united with the acid, in a whitish, semi-opaque mass. A solution of this mixed in distilled water, deposited a quantity of a yellowish powder; which, by distillation in a glass retort, was in great part revived into a running mercury. A part also remained dissolved in the clear liquor; for a drop let fall on polished copper instantly whitened it. (8.) Regulus of antimony melted with the vitreous salt, lost eight or nine grains, (about $\frac{1}{5}$); the regulus assumed a fine, brilliant, striated appearance; the scoriæ were somewhat opaque. (9.) Bismuth lost eight grains; the scoriæ were like the preceding, but the bismuth itself suffered little change. (10.) Zinç, mixed with the salt, and distilled in a glass retort, yielded a true phosphorus, which arose in a very moderate heat. The residuum was of a grey colour, a little melted at

Acid of phosphorus and its combinations.

the bottom, in weight not exceeding two drachms; so that two scruples had sublimed. This residuum, urged further in a small Hessian crucible to perfect fusion, emitted an infinity of phosphorine flashes, with a kind of detonation. The matter, grown cold, looked like the scoriæ of melted glass. (11.) White arsenic, mixed with this salt, separated in the fire, greatest part of it subliming, and only as much remaining behind as increased the weight of the salt eight or nine grains. This compound appeared at first transparent; but, on being exposed to the air, became moist, and of an opaque whiteness, much resembling crystalline arsenic. (12.) Cinnabar totally sublimed; suffering no change itself, and occasioning none in the salt. Sulphur did the same. (13.) One part of the salt, mixed with ten of manganese, and melted in a close vessel, gave a semitransparent mass, some parts of which were bluish. The crucible was lined with a fine purple glazing, and the edges of the mass itself appeared of the same colour.

"The vitreous salt dissolved also, in fusion, metallic calces and earths. Chalk, with one-third its weight of the salt, formed a semitransparent vitreous mass: calcined marble, with the same proportion, flowed so thin as to run all through the crucible; gypsum, likewise, ran mostly through the crucible; what remained was semitransparent. Lapis specularis ran entirely through the vessel. Spanish chalk gave a semitransparent mass, which sparkled on breaking; and fine white clay, a similar one. Saxon topaz and flint were changed into beautiful opal-coloured masses; the earth of alum into a semitransparent mass, and quicklime into an opaque white one. The mass with flints imbibed moisture from the air; the others not.

"Oil of vitriol, poured upon one-fourth its weight of this salt in a retort, raised an effervescence, acquired a brownish colour, and afterwards became turbid and white. On raising the fire, the oil of vitriol distilled, and the matter in the bottom of the retort melted. In the neck was found a little sublimate, which grew moist in the air; as did likewise the remaining salt, which was opaque and whitish. Concentrated spirit of nitre, distilled with this salt in the above proportion, came over unchanged; no sublimate appeared; the residuum looked like glass of borax. The distilled spirit did not act in the least upon gold, even by coction. Strong spirit of sea-salt being distilled in the same manner, no sensible change was made either in the spirit or the salt.

"Equal parts of the vitrified microcosmic salt and salt of tartar being urged with the strongest fire that a glass retort could bear, nothing sensible came over, nor did the mixture appear in thin fusion. Dissolved in water, filtered, and duly evaporated, it afforded, very difficultly, oblong crystals, somewhat alkaline; the quantity of alkali having been more than enough to saturate the acid. A whitish matter remained on the filter, amounting to seven or eight grains, from two drachms of the mixture; this, after being washed and dried, melted before a blow-pipe, as did likewise the crystals.

907 Expels the acids of vitriolated tartar, nitre, and sea-salt.

"This salt seems to extricate, in part, the acids of vitriolated tartar, nitre, and sea-salt. (1.) On distilling a mixture of it with an equal quantity of vitriolated tartar, there came over some ponderous acid drops, which, saturated with fixed alkali, formed a neutral salt greatly resembling the vitriolated tartar. The residuum readily dissolved in water, and difficultly crystallized. (2.) Nitre, treated with the same proportion of the salt, began to emit red vapours. The residuum was of a peach-blossom colour, appeared to have melted less perfectly than the preceding, and dissolved more difficultly in water. The solution deposited a little earthy matter; and, on being slowly evaporated, shot into crystals, which did not deflagrate in the fire. (3.) Sea-salt, distilled in the same manner, manifestly parted with its acid; the residuum was whitish, readily dissolved in water, and afforded some cubical crystals. (4.) Sal ammoniac suffered no change. (5.) Borax, with an equal quantity of vitreous salt, run all through the crucibles.

"Solutions of this salt precipitated the earthy part of lime-water, of solution of alum, of flint dissolved in fixed alkali, and the combination of marine acid with chalk or quicklime. The precipitate from this last liquor is tenacious like glue, and does not dissolve even in boiling water; exposed to a strong fire, it froths prodigiously, and at last melts into a thick scoria.

"Solutions of this salt precipitate also sundry metallic solutions; as butter of antimony, solutions of silver, copper, lead, iron, mercury, and bismuth, in the nitrous acid; and of tin in aqua-regis. The precipitate of iron from spirit of salt is a tenacious mass; that of silver from aquafortis, sometimes a white powder, sometimes tenacious. Copper from aquafortis is sometimes thrown down in form of a white powder, and sometimes in that of a green oil, according to the proportions and diluteness of the liquor. Silver is not precipitated at all by this acid from its solution in vinegar, nor gold from aqua-regis.

"An ounce of the vitreous salt, well mixed with half an ounce of soot, and committed to distillation, yielded a drachm of fine phosphorus. The black residuum, being elixated with boiling water, and the liquor passed through a filter, there remained upon the filter eight scruples of a black matter; and, on evaporating and crystallizing the liquor, about seven drachms were obtained of oblong crystals, which did not deliquate in a moist air, but became powdery in a warm one. These crystals, treated afresh with inflammable matter, yielded no phosphorus. Before a blow-pipe they melted into a transparent globular mass, which on cooling, became turbid and opaque. Dissolved in water, they precipitated solutions of silver, mercury, copper, and of chalk; though they did not act upon the latter so powerfully, nor produce with it a gluey mass, as before they had been deprived of their phosphorine acid."

Mr Wiegleb informs us, that the phosphoric acid exhibits less affinity with calcareous earth, in the moist way, than the vitriolic; though it cannot be separated from the ultimate residuum of the calcareous earth by that acid. It expels, however, all the liquid acids from their basis in the dry way. It precipitates iron from a solution in vitriolic acid, of a perfectly white colour. For the uses of this acid as a flux, see the article *Blow-pipe*.

§ 10. *Of the Acid of Ants.*

2d 907 How procured.

The acid may be obtained from these insects either by

Acid of phosphorus and its combinations.

by distillation, or simple infusion in water. From twenty-four ounces of ants, Neumann obtained eleven ounces and a half of acid as strong as good vinegar, by distillation in balneo mariæ. Of this acid, Mr Margraaf gives the following account in the Berlin Memoirs for 1749.

908 Its properties.

"The acid of ants effervesces with alkaline salts, both fixed and volatile. With volatile alkalies it forms a neutral liquor, which, like that composed of the same alkalies and vinegar, yields no concrete salt on distillation. With fixed alkalies it concretes, upon proper exhalation, into oblong crystals, which deliquate in the air. The crystals, or the saturated neutral liquor uncrystallized, on being distilled with a fire increased till the retort began to melt, yielded, a liquor scarce sensibly acid, and afterwards a small quantity of an urinous and partly ammoniacal liquor. The remaining black matter, dissolved in distilled water, filtered and evaporated, shot into large crystals which did not deliquate in the air, though they were in taste strongly alkaline, effervesced with acids, and had all the other properties by which fixed alkalies are distinguished.

"This acid dissolves, with great effervescence, coral, chalk and quicklime; and concretes with them all into crystals which do not deliquate in the air.

"It does not precipitate silver, lead, or mercury, from the nitrous acid; nor quicklime from the marine. Hence it appears to have no analogy to the marine or vitriolic acids; the first of which constantly precipitates the metallic solutions, and the other the earthy.

"It does not act upon filings of silver; but (like vegetable acids), it totally dissolves, by the assistance of heat, the calx of silver precipitated from aquafortis by salt of tartar.

"It does not dissolve calces of mercury, (as vegetable acids do); but revives them into running quicksilver.

"It acts very weakly upon filings of copper; but perfectly dissolves copper that has been calcined. The solution yields beautiful compact green crystals.

"It dissolves iron-filings with violence; the solution duly evaporated, shoots into crystals more readily than that made in distilled vinegar. It scarcely acts at all upon filings of tin.

"It does not, according to Mr Margraaf, corrode filings of lead; but dissolves, by the assistance of heat the red calx of lead. The solution crystallizes into a saccharum saturni. In Mr Ray's philosophical letters, it is said, that *lead* put into the acid spirit, or fair water, together with the animals themselves, makes a good *saccharum saturni*; and that this saccharum, on being distilled will afford the same acid spirit again, which the saccharum saturni made with vinegar will not do, but returns an inflammable oil with water, but nothing that is acid; and saccharum saturni made with spirit of verdegris doth the same in this respect with the spirit of pismires.

"It dissolves zinc with vehemence, and shoots, upon due evaporation, into inelegant crystals, not at all like those produced with distilled vinegar. On bismuth, or regulus of antimony, it has little effect, either when calcined or in their metalline state.

§ 11. *Of the Acid of* Amber.

Acid of amber and its combinations.

The nature of this acid is as yet but little known, and Mr Pott is the only chemist who seems to have examined it with accuracy. We shall therefore give an abstract of the principal observations and experiments he has made on this salt.

909 Mr Pott's experiments.

"Salt of amber requires a large quantity of water for its solution. In the first crystallization (being much impregnated with the oil which rises from the amber along with it), it shoots into spongy flakes, in colour resembling brown sugar-candy; the crystals which succeed prove darker and darker coloured. On repeating the depuration, the crystals appear at top of a clear yellow or whitish colour, in form of long needles or feathers; at bottom, darker, and more irregular, as are likewise the crystals which shoot afterwards. The crystals neither liquefy nor become powdry in the air: rubbed, they emit a pungent smell like that of radishes, especially if warmed a little; their taste is acid, not in the least corrosive, but with a kind of oily pungency.

"This salt, kept in the heat of boiling water, loses nothing of its weight, and suffers no alteration. In a great heat it melts like oil; after which a little oily acid arises, then oily striæ appear in the lower part of the retort, and the salt sublimes into the neck, partly in the form of a dark yellow butter, and partly in that of feathers, a black coaly matter remaining at bottom; so that, by this process, a part of the salt is destroyed.

"Oil of turpentine has no action on this salt. Highly rectified spirit of wine gains from it a yellow colour in the cold; and, on the application of heat, dissolves a considerable quantity, but deposites great part of it on cooling. The salt thus deposited is somewhat whiter than before, but still continues sensibly yellow. The dulcified spirit of sal ammoniac dissolves it readily, without effervescence, into a yellow liquour; if the salt was foul, the solution proves of a red colour; on burning of the vinous spirit, a neutral liquor remains.

"A solution of salt of amber in water, saturated with a pure alkaline lixivium, yielded, on inspissation, a saline matter, which would not crystallize, and which when exsiccated by heat, deliquated in the air, leaving a considerable proportion of an earthy, unctuous matter. Being again gently inspissated, it left a brownish salt very soluble, weighing one half more than the salt of amber employed. This salt effervesced with the vitriolic and nitrous acids: the vapour, which exhaled, was not acid, but oily and sulphureous. On repeating the experiment, and fully saturating the alkali with the salt of amber, the neutral salt made no effervescence with these acids. This salt did not perfectly melt before a blow-pipe; continued in the fire for some time, it effervesced with aquafortis. In distillation it yielded a bitter, oily, alkalescent spirit, much resembling the spirit of tartar; and towards the end, an empyreumatic oil. The residuum elixated, yielded the alkaline salt again of a brown colour.

"Salt of amber effervesces strongly with volatile alkalies; and, on saturation, forms with them an oily am-

Acid of amber and its combinations.

ammoniacal liquor, which, in distillation, totally arises in a fluid form, except that a small portion of a penetrating, oily, saline matter, concretes towards the end.

910 Extricates the acids of sal ammoniac and nitre.

"On distilling salt of amber with an equal quantity of common sal ammoniac, a marine acid spirit came over, of a strong smell, and a brown colour: afterwards, a little white sal ammoniac sublimed; at length arose suddenly a large quantity of a fuliginous or bituminous matter, leaving behind a small portion of a like shining black substance. The coaly matter was considerably more in quantity than the salt of amber employed. On treating it with nitre, red vapours arose, and the mixture detonated with violence. A mixture of it with borax, frothed and swelled up much more than borax by itself; and, on raising the fire, yielded only some oily drops; the acid being destroyed by this salt, as by fixed alkalies and quicklime.

911 Purified by the marine acid.

"Spirit of sea-salt, poured upon one-fourth its weight of salt of amber, made scarce any solution in the cold: on the application of heat, nearly the whole coagulated into the consistence of a jelly. In distillation, the spirit of salt arose first; then almost the whole of the salt of amber, partly like firm butter, partly like long striated plumous alum, very pure, and of a fine white colour, its oily matter being changed into a coal at the bottom. The salt, thus purified, makes no precipitation in the solution of silver, and consequently retains nothing of the marine acid; nor does it precipitate solution of quicklime made in spirit of salt, and consequently contains nothing vitriolic. If any of the mineral acids was contained in this salt, it could not here escape discovery; the oil, which in the rough salt is supposed to conceal the acid, being in this process separated.

912 Effects of spirit of nitre on it.

"Aquafortis being poured upon one-fourth its weight of salt of amber, extracted a yellowish colour from it in the cold, but dissolved little: on the application of heat, the whole dissolves into a clear liquor, without any coagulation: if the salt is very oily, the solution proves red. In distillation, the greatest part arises in a liquid form, with only a very small quantity of concrete salt. The spirit does not act upon gold, but dissolves silver, and quicksilver, as at first; a proof that it has received no marine acid from the salt of amber.

913 Of oil of vitriol.

"Oil of vitriol being added to twice its weight of salt of amber diluted with a little water, a moderate fire elevated an acidulous, liquor, which appeared to proceed from the salt of amber; for its making no change in solution of fixed sal ammoniac, showed it not to be vitriolic. On continuing the distillation by a stronger fire, greatest part of the salt arises undestroyed, and the oil of vitriol along with it; a black, light, porous earth remaining.

914 Of quicksilver.

"Equal parts of quicklime and salt of amber gave over in distillation only an acidulous phlegm; the residuum, elixated with water, yielded a solution of the lime in the acid of amber, resembling a solution of the same earth in vegetable acids, precipitable by alkaline salts, and by the vitriolic acid. Lime, added to a watery solution of salt of amber, dissolves with some effervescence; after which, the whole coagulates into the consistence of a jelly: this, diluted with water, proves similar to the foregoing solution.

"Solution of salt of amber makes no precipitation in solution of silver or quicksilver. It dissolves zinc, as all acids do: fixed alkalies precipitate the zinc: the volatile do not; and when a sufficient quantity of the volatile has been added, the fixed make no precipitation. It acts exceedingly slowly and difficultly upon copper; but corrodes calcined copper in a shorter time. It soon corrodes iron, by coction, into a crocus, and dissolves a part into a liquid form: the solution has little colour; but alkaine salts readily discover that it holds iron, by rendering it turbid and whitish, and throwing down a considerable quantity of a greenish calx."

915 Effects of salt of amber on the metals.

Acid of arsenic and its combinations.

§ 12. *Of the acid of* Arsenic.

916 How first discovered.

Mr Scheele first perceived, from some experiments on manganese, that arsenic contained phlogiston: from whence he was led to an analysis of this substance, which produced an acid of a very singular kind; by uniting of which with phlogiston in certain proportions, either white arsenic or its regulus may be composed at pleasure.

917 Two ways of decompounding arsenic.

White arsenic may be decompounded in two ways. 1. Put two ounces of it reduced to a fine powder in a glass mortar into a retort of the same materials; pour upon it seven ounces of pure muriatic acid, whose specific gravity is to that of water as 10 to 8; and lute on a receiver. The arsenic is quickly dissolved in a boiling heat, which must be brought on as quickly as possible. After the solution is accomplished, while the liquor is still warm, three ounces and a half of nitrous acid, of the same specific gravity with the muriatic above-mentioned, is to be added, and the liquid which had already gone over into the receiver poured back. The receiver is then to be put on again, but not luted; the mixture soon begins to effervesce, and red vapours go over into the receiver. The distillation is to be continued till these vapours cease; when an ounce of finely powdered arsenic is again to be added, the receiver applied as before, and a gentle ebullition continued till the second quantity of arsenic be dissolved. An ounce and an half of nitrous acid is then to be added, and the mixture distilled to dryness, increasing the fire towards the end, so as to make the retort red hot. The acid which comes over into the receiver may serve again several times. The white mass which remains in the retort is the dry acid of arsenic. It may be reduced to a liquid form by pouring upon it, in coarse powder, twice its weight of distilled water, and boiling for a few minutes, pouring back the liquor which comes over, and afterwards filtering the solution through blotting paper, which has been previously washed in hot water.

918 By means of nitrous acid.

In this process the nitrous acid attacks the phlogiston of the arsenic, is volatilized in consequence of its union with it, and leaves the more fixed but less powerful acid of arsenic behind. The nitrous acid would alone be sufficient for this purpose, could it accurately come into contact with the particles of arsenic; but this cannot be done without solution, and the nitrous acid is capable of dissolving arsenic only in pro-

Acid of arſenic and its combinations.

proportion to the water it contains. Too great a quantity would therefore be required were this acid to be uſed by itſelf; but by the uſe of muriatic acid for the ſolution, a ſmaller quantity of ſpirit of nitre is admitted to intimate contact with all the arſenical particles, and has an opportunity of depriving them of their phlogiſton. Aqua-regia might be poured upon the arſenic at once; but the greateſt efferveſcence it excites would throw the mineral up to the top in ſuch a manner that the menſtruum could not act upon it. By the operation of dephlogiſtication, arſenic loſes a fifth part, which is ſuppoſed to be pure phlogiſton.

919 By dephlogiſticated ſpirit of ſalt.

The other method of decompoſing arſenic is, by means of the dephlogiſticated ſpirit of ſalt. For this purpoſe, take one part of powdered mangaueſe, and mix it with three of the muriatic acid above-mentioned. Put it into a retort, of which it may fill one-fourth; a receiver containing one-fourth of powdered arſenic, with one-eighth of diſtilled water, is to be luted on, and the retort put into a ſand-bath. The dephlogiſticated muriatic acid, going over into the receiver, is inſtantly abſorbed by the arſenic; which ſome hours afterwards will be diſſolved, and two different liquid ſtrata, which cannot be mixed together, will be perceived in the receiver. This ſolution is now to be put into a clean glaſs retort, and diſtilled to dryneſs; increaſing the fire at laſt to ſuch a degree as to make the whole red hot: and in this proceſs alſo two different liquids paſs over into the receiver which do not unite together.

Here the mangaueſe attracts the phlogiſton of the muriatic acid; and as this dephlogiſticated acid has a very ſtrong attraction for phlogiſton, it deprives the arſenic of its phlogiſton, and thus recompoſes the ordinary phlogiſticated muriatic acid. This portion of recompoſed acid diſſolves part of the arſenic, forming with it what is called *butter of arſenic*. The other part of the arſenic which has been decompoſed, diſſolves in the water, and forms a liquid ſpecifically lighter than the butter, and therefore ſwims above it. On rectifying the two liquids, the undecompoſed portion of the arſenic ariſes along with the muriatic acid, and goes over into the receiver in form of an heavy oil, while the acid of arſenic remains behind in the retort. The acid obtained in this way is preciſely the ſame with the former, and one would hardly believe that it is an acid, becauſe it has no acid taſte; but after ſome days it grows moiſt in the air, and at laſt deliquates, aſſuming the appearance of oil of vitriol. As the deliqueſcence, however, is very ſlow, it is proper to diſſolve it in a certain quantity of water, when a ſmall quantity of white powder remains undiſſolved, after preparing it by the firſt proceſs, which is ſiliceous earth derived from the retort. This ought to be carefully ſeparated from the acid by filtration; and in order to prevent the glue of the blotting-paper from mixing with the acid, it was directed to waſh the filter with hot water previous to the operation.

920 Acid of arſenic equally poiſonous with the white arſenic itſelf.

The firſt experiment M. Scheele tried on this acid after he had obtained it, was to diſcover if it was as noxious to animals as when combined with phlogiſton. Having mixed a little with honey, the flies that eat of it died in an hour; and eight grains reduced a cat to the point of death in two hours. Some milk, however, being then given to the animal, it vomited violently, and ran away.

Acid of arſenic and its combinations.

2. An ounce of dry acid of arſenic, heated in a ſmall phial to near the point of ignition, melts into a clear liquid, which congeals when cold; but if the heat be increaſed till the veſſel begins to melt, the acid begins to boil, reſumes its phlogiſton, and arſenic ſublimes in greater quantity as the heat is longer continued. After ſubjecting the acid to this violent heat in a retort for an hour, the veſſel melted, and the acid had riſen up as high as the neck.

921 Eaſily reſumes its phlogiſton.

3. In a crucible the arſenic attracts phlogiſton in greater quantity, and is entirely diſſipated in arſenical vapours; a little clear and difficultly fuſible glaſs, conſiſting of clay and the acid of arſenic, remaining in the crucible.

922 Takes fire and ſublimes charcoal.

3. With powder of charcoal the arſenical acid undergoes no change; but if the mixture be put into a retort, the moiſture all driven off, a receiver then luted on, and the heat increaſed till the bottom of the retort becomes red hot, the whole maſs takes fire with violence; all the acid is reduced, and ſublimed into the neck of the retort; a ſhining regulus is obtained, mixed with a little arſenic and charcoal duſt. A few drops of water are found in the receiver, but they do not contain a particle of acid.

923 Appearance with oil of turpentine, &c.

4. The arſenical acid, after ſome days digeſtion with oil of turpentine, unctuous oil, and ſugar, becomes black and thick. If ſome muriatic acid be diſtilled from this, a little nitrous acid added, and the diſtillation repeated, ſome acid of arſenic is left behind. Spirit of wine undergoes no change either by digeſtion or diſtillation with arſenical acid.

924 With ſulphur.

5. Six parts of acid digeſted with one of ſulphur ſuffer no change; but when the mixture is evaporated to dryneſs, and then ſubjected to diſtillation in a glaſs retort, the two unite with great violence at that degree of heat in which ſulphur melts; and the whole maſs riſes almoſt in the ſame inſtant, in form of a red ſublimate; a little ſulphureous acid in the mean time going over into the receiver.

925 Combined with vegetable fixed alkali.

6. Acid of arſenic, ſaturated with vegetable fixed alkali, forms a deliqueſcent ſalt which does not cryſtallize, but turns ſyrup of a violet green, though it produces no change on the tincture of lacmus. On the addition of a little more acid, however, when it reddens lacmus, but makes no alteration on the ſyrup of violets, the liquor will afford fine cryſtals like Mr Macquer's neutral ſalt of arſenic. On keeping this ſalt for an hour in fuſion in a crucible covered with another luted upon it, the inſide of the veſſel was found covered with a white glazing, and a ſalt remained, which was ſtill the ſame arſenicated ſalt with exceſs of acid.

926 This ſalt decompoſed by charcoal.

7. On diſtilling this ſalt in a retort with an eighth-part of charcoal-duſt, it began to boil very violently as ſoon as the retort became red-hot, and a very fine regulus of arſenic ſublimed. The black reſiduum contained the alkali entirely ſeparated from the arſenical acid.

927 Combined with mineral alkali.

8. With mineral alkali the acid of arſenic forms cryſtals when perfectly neutralized, but not if added to exceſs. In that caſe, the maſs becomes deliqueſcent like the former when neutral.

928 With volatile alkali.

9. With volatile alkali a ſalt much reſembling the two

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two former is produced. It does not change lacmus, but turns the syrup of violets green. A gentle heat drives off part of its volatile alkali, and leaves the remainder supersaturated with acid; in which case it shoots into long radiated and deliquescent crystals. These, urged by a stronger heat, part with the whole of their alkali, which is partly decomposed; some arsenic is formed by the union of the phlogiston of the alkali with part of the arsenical acid; the remainder of which assumes a milky colour, and lies in the
929. bottom of the retort.

Expels the acid of vitriolated tartar by dry distillation.

10. Acid of arsenic distilled with vitriolated tartar expels the vitriolic acid in a violent heat, which comes over in a concentrated but sulphureous state, leaving the arsenical salt formed of the acid and alkali united. With Glauber's salt the vitriolic acid also rises, and with
930 less heat than when vitriolated tartar is made use of.

Acid of nitre;

11. One part of nitre distilled with three of acid of arsenic, yielded a spirit of nitre, together with the
931 neutral arsenical salt already mentioned.

Of common salt.

12. One part of common salt with three of arsenical acid, yielded some smoking part of salt. The residuum dissolved in water gave crystals of common salt, and a thick magnum, which would not crystallize till the superfluous arsenical acid was taken away by adding powdered chalk, when it yielded crystals
932 similar to those produced by the acid and pure alkali.

Phenomena with sal ammoniac.

13. With sal ammoniac the product was first fuming muriatic acid, then volatile alkali in a liquid state, after that arsenic, and lastly part of the arsenical acid
633 remained in the retort.

Decomposes spathum ponderosum and gypsum.

14. Spathum ponderosum, and gypsum, both parted with their acids, which were become sulphureous. The former did not yield its acid till the retort began to melt.

15. One part of fluor mineral was mixed with four
634 of acid of arsenic, and distilled into a receiver having a little water in it. When the retort grew red-hot, first a yellow and then a red substance sublimed. Some sulphureous acid, but none of the acid of fluor, went over. A grey-coloured residuum was left in the retort; which being divided into two parts, one was mixed with charcoal-powder and distilled with a strong fire, without the production of either arsenic or regulus; the other was mixed with four parts of acid of arsenic, and subjected to a second distillation. When the mass grew dry, a little yellow sal ammoniac was sublimed, and the water was covered with a crust of sili-
635 ceous earth, as in the usual distillations of that mineral.

Cannot expel the fluor acid.

Precipitates lime water

16. Arsenical acid precipitates lime-water, by uniting with the calcareous earth dissolved in it. By the addition of more acid, the precipitate is dissolved, and the liquor yields small crystals, which let fall a sele-
636 nite on the addition of vitriolic acid.

Phenomena with chalk.

17. On the addition of powdered chalk to arsenical acid diluted with water, the earth is at first dissolved, but by adding more chalk the whole is coagulated in-
937 to small crystals.

With magnesia.

18. Magnesia dissolves in the arsenical acid, and the solution coagulates when it comes to the point of saturation. On dissolving the coagulum in a larger quantity of water, it becomes gelatinous by evaporation; and if the jelly be lixiviated with water, filtered, and evaporated, a viscid mass remains, which refuses to crystallize.

Acid of arsenic and its combinations.

19. Earth of alum precipitated by alkali of tartar, is easily soluble in arsenical acid, and coagulates as soon as it arrives at the point of saturation. Evaporated to dryness, mixed with some charcoal powder, and then subjected to strong distillation, a little yellow 938
sublimate arises into the neck of the retort, as likewise some shining regulus, while a volatile sulphureous acid passes over into the receiver. The residuum dissolves with difficulty in the vitriolic acid, though some crystals of alum will form in the space of two months. 939

With earth of alum.

With white clay.

20. Four parts of arsenical acid mixed with one of powdered white clay, did not dissolve any part by digestion for a fortnight. By distillation in a retort till the vessel began to melt, it was converted into a thick flux, and a little arsenic sublimed. By mixing the residuum with a little powdered charcoal, a shining regulus was sublimed. 940

With terra ponderosa.

21. Terra ponderosa dissolves readily in the acid of arsenic, but precipitates again as soon as it has attained the point of saturation. The solution is precipitated by acid of vitriol, and forms regenerated ponderous spar. 941

With gold.

22. Gold is not acted upon by acid of arsenic, either by digestion or otherwise; nor is its solution precipitated, though the retorts used in the operation were stained with red and yellow spots, which could not be taken off; nor is its action increased by mixture with muriatic or with nitrous acid. 942

Platina.

23. Pure platina is not acted upon. Its solution is not precipitated by the pure arsenical acid, but readily by the arsenical salts. The precipitate is yellow, and dissolves in a large quantity of water, but contains no mark of arsenical acid. Addition of muriatic or of nitrous acid makes no change in its effects. 943

Silver.

24. Pure silver is not acted upon by the arsenical acid in digestion. On augmenting the fire till the acid melted, and keeping up this degree of heat for half an hour, the metal dissolved, and on breaking the retort, a colourless glassy mass, nearly transparent, was found in it; the retort being covered with a flame-coloured glazing, which could not be separated from it. By a great degree of heat the silver was reduced without addition. Solution of silver is precipitated by pure acid of arsenic, but more effectually by the neutral arsenical salts: the precipitate is of a brown colour, and by digestion in muriatic acid is changed into lunea cornea; it is also soluble in spirit of sal ammoniac prepared with quicklime. The action of the arsenical acid upon silver is considerably increased by mixing it with spirit of sea-salt; the former attacking the phlogiston of the metal, while the latter attacks its earthy basis. 944

Quicksilver.

25. Quicksilver is not acted upon by digestion with arsenical acid. On putting the mixture into a retort, distilling to dryness, and then increasing the fire, the mass becomes yellow, quicksilver rises into the neck of the retort, with a little arsenic, and some yellow sublimate; but though the fire was augmented till the retort began to melt, the mass could not be fused. Three drachms and an half of quicksilver were obtained out of six employed in the experiment; the arsenical acid, therefore, contained two and an half. The mass was somewhat yellow: it dissolved very readily in muriatic acid, but scarcely at all in the nitrous or vitriolic; on evaporation to dryness and distillation, some corrosive sublimate

Acid of arſenic and its combinations.

ſublimate roſe into the neck of the retort; the reſiduum, melted in a very ſtrong fire, proved to be acid arſenic. Another portion of the maſs, diſtilled with two parts of common ſalt, yielded corroſive ſublimate.

945 With corroſive ſublimate.

26. Acid of arſenic diſtilled with corroſive ſublimate undergoes no change; but by ſublimation with mercurius dulcis, a corroſive ſublimate is obtained. Some have aſſerted, that by ſubliming arſenic with corroſive ſublimate, a butter of arſenic is obtained; but Mr Scheele informs us that this is a miſtake; and that by diſtilling this mixture, he conſtantly obtained corroſive ſublimate at firſt, and arſenic afterwards. With regulus of arſenic, however, a ſmoking butter of arſenic, mercurius dulcis, and ſome quickſilver, are obtained. The ſame thing happens with a mixture of orpiment and corroſive ſublimate.

946 Butter of arſenic is not obtained by this proceſs.

947 With copper.

27. Arſenical acid diſſolves copper by a digeſting heat. The ſolution is of a green colour: a quantity of light blue powder is depoſited, and attaches itſelf to the copper. This powder conſiſts of the acid of arſenic and calcined copper. On mixing two parts of dry acid of arſenic, in fine powder, with one of filings of copper, and diſtilling the mixture, ſome arſenic roſe into the neck, and the maſs melted and turned blue. On boiling it with water, the ſolution was ſimilar to one made directly from acid of arſenic and copper. A little copper remained in the bottom of the retort, which was tinged with brown, red, and yellow ſpots, inſoluble in any menſtruum. The ſolutions of this metal are not precipitated by arſenical acid, but the acetous ſolution is. Neutral arſenical ſalts throw down a blue precipitate, which by expoſure to a ſtrong fire, turns brown and covers the inſide of the containing veſſel with a yellow enamel. On mixing the ſcoria in a fine powder with a little lamp-black, ſome fine regulus of arſenic ſublimed, and the copper in the reſiduum was reduced.

948 With iron.

28. With iron the acid of arſenic forms a gelatinous ſolution, which by expoſure to the air grows ſo thick that in two hours time it will not flow out at the mouth of a phial. With alkali of tartar a whitiſh green powder is thrown down; which being edulcorated and diſtilled in a glaſs retort, yields ſome arſenic, and leaves a red ochre behind. On diſtilling four parts of arſenical acid with one of iron filings, the maſs effervesced ſtrongly towards the end; and when it became dry, took fire in the retort upon increaſing the heat, when both arſenic and regulus of arſenic were ſublimed. The reſiduum was black, friable, and contained but little acid of arſenic; the retort was covered with yellowiſh brown ſpots. Solutions of iron in mineral acids are not precipitated by acid of arſenic, but the acetous ſolution lets fall a dark brown powder. All the ſolutions are precipitated by the arſenical neutral ſalts, the precipitates by a ſtrong fire, converted into black ſcoriæ; which mixed with powdered charcoal, and calcined, yield copious vapours of arſenic, and are afterwards attracted by the magnet.

949 With lead.

29. Lead digeſted with arſenical acid turns black at firſt, but in a few days is ſurrrounded with a light greyiſh powder, containing ſome arſenic which may be ſeparated by ſublimation. On diſtilling one part of ſhavings of lead with two of dry acid of arſenic, the lead was diſſolved, the maſs flowed clear, and a little arſenic roſe into the neck of the retort. A milky glaſs was found in the bottom, which by boiling in diſtilled water, let fall a quantity of white powder, the ſuperfluous acid being diſſolved in the water; the edulcorated powder yielded regulus of arſenic by diſtillation with charcoal. Solutions of lead in nitrous and muriatic acids are precipitated by arſenical acid.

950 With tin.

30. Tin digeſted with acid of arſenic becomes firſt black, then is covered with a white powder, and afterwards becomes gelatinous. One part of tin filings diſtilled with two of acid of arſenic, took fire as ſoon as the retort became red-hot, and immediately after both arſenic and a little regulus were ſublimed. The tin was diſſolved into a limpid liquor, which became milky when cold.—By waſhing in water, a quantity of white powder was ſeparated, inſoluble in any acid, and containing very little of that of arſenic.

951 With zinc.

31. Arſenical acid diſſolves zinc with effervescence. The metal grows black, and the tranſparency of the acid is deſtroyed by a quantity of black powder. This powder edulcorated, dried, and put on an iron plate heated nearly red-hot, emits a blue flame and white arſenical ſmoke in the dark, leaving behind a white powder; thus manifeſting itſelf to be moſtly regulus of arſenic. One part of filings of zinc diſtilled with two of acid of arſenic, took fire in the retort with a very bright flame, and burſt the veſſel with an exploſion. Some regulus of arſenic and flowers of zinc were found in the neck.

952 With biſmuth.

32. Biſmuth digeſted with acid of arſenic is covered with a white powder; water precipitates the ſolution, and the precipitate conſiſts of calcined biſmuth and acid of arſenic. On diſtilling one part of the biſmuth with three of arſenical acid, the maſs melted, the metal was calcined, but remained undiſſolved in the bottom of the veſſel; a little arſenic roſe into the neck; and after the retort became cool, water was poured on the reſiduum, which diſſolved the acid, but the calx of biſmuth remained unchanged. Solution of this ſemimetal in the acid of nitre was precipitated by arſenical acid. This precipitate, as well as the calx, are very difficult of fuſion, but on adding a little powdered charcoal, the mixture inſtantly melts, the arſenic goes off in vapours, and the biſmuth is reduced.

953 Regulus of antimony.

33. With regulus of antimony a quantity of white powder is produced by digeſtion, and the clear ſolution is likewiſe precipitated by dropping it into pure water. This powder is ſoluble only by muriatic acid, and may be precipitated again by the addition of water. One part of regulus of antimony diſtilled with three parts of arſenical acid, took fire as ſoon as the maſs melted, and regulus of arſenic with a red matter were ſublimed; a little volatile ſulphureous acid came over into the receiver. On boiling the reſiduum in water, the acid was diſſolved, a white ſhining powder remained behind, which on being mixed with charcoal powder and diſtilled, an ebullition took place, ſome regulus of arſenic roſe into the neck of the retort, and the antimony was reduced. Butter of antimony was not precipitated by the pure acid, but very readily by the arſenical ſalts. Acetous and tartareous ſolutions of glaſs of antimony are preciptated by arſenical acid

Acid of arsenic and its combinations.

954 With cobalt.

34. Cobalt is partially dissolved, and the solution assumes a rose-colour; on putting the whole mass into a retort, distilling off the liquid, and then augmenting the fire, the mass melted, and a little arsenic was sublimed. The residuum when cold had a semi-transparent violet colour. On pouring water upon it, and putting it on hot sand, the acid was dissolved, the violet colour disappeared, and the solution assumed a dark-red colour. The bottom of the retort had a blue tinge, which could not be taken off. Solutions of cobalt in mineral acids are readily precipitated by the arsenical neutral salts. The precipitate is of a rose-colour, but melts with difficulty into a dark blue scoria.

955 With nickel.

35. Nickel, with acid of arsenic, assumes a dark green colour, and lets fall a green powder containing arsenic in substance, which may be separated from it by a gentle heat. One part of nickel distilled with two of dry arsenical acid, melted with some appearance of inflammation, yielding some arsenic at the same time. The mass was yellow, with a number of grey elevated streaks upon it, which appeared like vegetation, and were formed during the distillation. On boiling the yellow mass in water, the acid was dissolved, leaving a yellow powder behind; which, when treated with charcoal-powder, yielded regulus of arsenic, but was not reduced itself. The solutions of nickel in acids are not precipitated by arsenical acid, not even that in vinegar, but the neutral arsenical salts throw down a whitish green powder.

956 With manganese.

36. Manganese in its natural state is dissolved only in small part; but when phlogisticated it dissolves readily and totally; though, whenever the acid arrives at the point of saturation, the solution coagulates into small crystals.

957 With regulus of arsenic.

37. Regulus of arsenic digested with its own acid soon becomes covered with a white powder, which is arsenic in substance. On distilling one part of the regulus with two of the acid, the former sublimed and the latter melted. If small pieces of regulus of arsenic be gradually added to the acid of arsenic in fusion, an inflammation takes place, and arsenic is sublimed.

2d 957 Strange phenomenon of arsenic with terra foliata tartari.

On distilling a mixture of equal parts of terra foliata tartari and arsenic, a limpid liquor like water first came over, smelling strongly of garlic; on changing the receiver, a liquor of a brownish red colour was collected, which filled the receiver with a thick cloud, emitting an intolerable smell of arsenic. On pouring this upon a filter, hardly a few drops had passed when a very thick stinking smoke suddenly arose as high as the cieling of the room; an ebullition ensued towards the edge of the filtering-paper, and a fine rose-coloured flame broke out, that lasted for some moments.

§ 13. *Of the Acid of* Molybdæna.

958 How to reduce molybdæna to powder.

We owe this, as well as the succeeding acids to the industry of the late Mr Scheele. The substance from which he extracted it is named by Cronstedt *molybdæna membranacea nitens*.—As this substance is of a flaky nature, and incapable of pulverization by itself, our author mixed some pieces of vitriolated tartar along with it in a glass mortar; by the attrition of which it was at last reduced to a fine powder, and which was afterwards freed from the vitriolated tartar by washing with hot water. He then treated this powder with all the known acids, but found none of them to have any effect upon it excepting those of arsenic and nitre.

Acid of molybdæna and its combinations.

959 Effects of the acid of arsenic upon it.

No sensible effect was perceived from the acid of arsenic until the water was evaporated; after which, by increasing the fire, a little yellow orpiment was sublimed in the neck of the retort, and some sulphureous acid passed over into the receiver.

960 Violent action of concentrated nitrous acid upon this substance.

On pouring two parts of concentrated nitrous acid upon one part of powdered molybdæna, the mixture was scarce warm in the retort, when it passed altogether into the recipient with great heat, and in the form of dark red vapours. Had the quantity been larger, he had no doubt that it would have taken fire; for which reason the experiment was repeated with diluted nitrous acid. Six ounces of diluted nitrous acid being poured on an ounce and a half of powdered molybdæna, no effect was perceptible till the liquor began to boil; after which a great number of red elastic vapours began to appear, and the mixture swelled considerably. The distillation being continued to dryness, the residuum appeared of a grey colour; the same quantity of nitrous acid was poured on, and the process repeated, when the residuum was whiter; and on still repeating the operation a fourth and fifth time, the remaining powder became at last as white as chalk. This residuum, after being edulcorated with hot water, was quite tasteless and insipid when dry. The limpid liquor which ran from it being evaporated to half an ounce, first assumed a fine blue colour, and then grew thick. On being examined, it was found to contain some iron, and was otherwise chiefly acid of vitriol. The colour disappeared on diluting the acid with water.

961 Acid of molybdæna obtained by fire alone.

The white powder just mentioned is the true acid of molybdæna, and may be obtained by the help of fire alone. A small piece of molybdæna exposed on a silver plate to the blow-pipe, makes a beautiful appearance, when the white vapours attach themselves to the plate in the form of small shining scales, in the direction of the flame. This white sublimate becomes blue whenever it is in contact with the blue flame; but changes to white whenever the point of the flame is directed against it. An ounce of powdered molybdæna was mixed with four ounces of purified nitre, and detonated in a crucible heated thoroughly red hot. The mass thus obtained was of a reddish colour. On dissolving it in water, the solution was clear and colourless. A small quantity of red powder fell to the bottom of the vessel; which, when dry, weighed 11 grains, and showed itself to be an iron ochre. By evaporation vitriolated tartar and nitre were obtained; but a good deal of lixivium remained, which refused to crystallize, though no mark of superfluous alkali remained. It was then mixed with some water, to which diluted acid of vitriol was added, until no more precipitate fell. The white powder which precipitated weighed three drachms; but if too much acid be added, the precipitate will be redissolved, and the water itself retains a part of it in solution. A precipitate is likewise obtained by means of nitrous or muriatic acid.

962 Its chemical properties.

The precipitate thus obtained, like those which result from the two former processes, is the true acid of molybdæna, and has the following chemical properties.

1. The

Acid of molybdæna and its combinations.

1. The ſolution reddens lacmus, coagulates a ſolution of ſoap, and precipitates hepar ſulphuris. 2. If this ſolution be boiled with the filings of any of the imperfect metals, it aſſumes a bluiſh colour. 3. By the addition of a little alkali of tartar, the earth becomes ſoluble in greater quantity in water; and after evaporation ſhoots into ſmall confuſed cryſtals. 4. Under the blow-pipe this earth is ſoon abſorbed by charcoal; but when placed on a ſilver plate it melts, and evaporates with the ſame phenomena as molybdæna itſelf. 5. By the addition of alkali, the earth is deprived of its property of being volatilized in the fire. 6. The ſolution, whilſt hot, ſhows its acid power more evidently than when cold, and tinges lacmus of a deeper colour. It effervеſces with chalk, with magneſia, and with earth of alum; with all of which it forms ſalts very difficult of ſolution in water. 7. It precipitates, from the nitrous acid, ſilver, quickſilver, and lead, as alſo lead diſſolved in marine acid. Theſe precipitates are reduced on burning charcoal, and the melted metal runs into the pores. Corroſive ſublimate is not precipitated; neither are the ſolutions of the other metals. 8. Terra ponderoſa is alſo precipitated from the nitrous and marine acids; and the precipitate is ſoluble in a large quantity of cold water. None of the ſolutions of the other earths are precipitated. 9. Fixed air is alſo expelled by this acid from the fixed and volatile alkalies, and forms with them neutral ſalts which precipitate all other metallic ſolutions. Gold, corroſive ſublimate, zinc, and manganeſe, are precipitated in form of a white powder; iron and tin, from their ſolution in marine acid, of a brown colour; cobalt of a roſe colour; copper of a blue; the ſolutions of alum and quicklime, white; and if the ammoniacal ſalt formed by the earth of molybdæna and volatile alkali be diſtilled, the earth parts with its alkali in a gentle heat, and remains in the retort in form of a grey powder. 10. Concentrated vitriolic acid diſſolves a great quantity of this earth by means of heat. The ſolution acquires a fine blue colour; which, however, diſappears on being heated, or by diluting the acid with water. In a ſtronger heat the acid flies off, leaving the earth unaltered behind. This ſolution becomes thick on cooling. 11. The nitrous acid has no effect upon the earth of molybdæna. 12. Boiled with the muriatic acid it diſſolves in conſiderable quantity; and, on diſtilling the mixture to dryneſs, a dark-blue reſiduum remains. On increaſing the heat, white flowers ariſe, with a little blue ſublimate, and a ſmoking muriatic acid is found in the receiver. The reſiduum is of a grey colour. Theſe flowers are only the earth of molybdæna volatilized by means of the muriatic acid, and therefore manifeſts the ſame properties. 13. If one part of this earth be diſtilled with two parts of vitriolated tartar, a little vitriolic acid paſſes over, at leaſt when the heat is very ſtrong; and the remaining earth is more ſoluble in water than before. 14. With two parts of nitre it expels, by means of diſtillation, a ſtrong nitrous acid; the reſiduum diſſolved in water is a neutral ſalt which precipitates all metallic ſolutions, and is ſimilar to that formed by a direct union of the acid and fixed alkali. 15. Diſtilled with two parts of pure common ſalt, the acid is expelled in a ſmoking ſtate, and white, yellow, and violet-coloured flowers ariſe, which become moiſt in the air, and when ſprinkled on metals give them a blue colour. Theſe flowers, as has been already remarked, are only the acid of molybdæna volatilized by that of ſea-ſalt.

Acid of molybdæna and its combinations.

963. Is capable of uniting with phlogiston.

The blue colour acquired by this earth on the contact of flame, alſo in the moiſt way in ſome caſes, ſhows that it is capable of contracting an union with the phlogiſton. To reduce this to certainty, Mr Scheele diſſolved ſome of the earth of molybdæna in boiling water, with the addition of a little alkali. Into this ſolution he poured ſome drops of muriatic acid, and divided it into ſeveral parts, into each of which he put filings of ſeveral metals. The ſolutions ſoon acquired a bluiſh colour, which grew deeper and deeper; and in an hour's time, during which the bottle was now and then ſhaken, the liquor aſſumed a fine dark blue. That this colour depends on phlogiſton, he infers from the following circumſtances: 1. If, inſtead of the metals themſelves, you take their calces, no blue colour is produced. 2. If there be dropped into the blue ſolution a few drops of acid of nitre, and the ſolution be then put into a warm place, the colour diſappears. It is therefore no matter of ſurpriſe, that both ſilver and quickſilver ſhould be attacked, ſince a double elective attraction takes place; the muriatic acid uniting with the metallic calx, and the earth of molybdæna with the phlogiſton of the metals. Gold, however, is not attacked in this way. 3. Too great a quantity of muriatic acid produces not a blue but a yellowiſh colour, which at laſt turns brown if the mixture be digeſted; but on adding this ſolution to a ſolution of the earth of molybdæna, a blue colour as uſual is produced. 4. Lixivium ſanguinis, in which the acid prevails, throws down the earth of a brown colour, and the infuſion of galls of a dark brown.

964. Shows no ſign of containing any metal.

The acid of molybdæna, treated with various fluxes, and with charcoal, ſhows no ſigns of containing any metallic matter. Moiſtened with oil-olive, and committed to diſtillation in a ſtrong fire, it did not ſublime, but remained in the retort in the form of a black powder; which, on being calcined in a crucible, ſublimed in white flowers as uſual. On inverting another crucible into the former, and luting the juncture, the earth remained unchanged and of a black colour, without any ſign of fuſion. This black powder did not diſſolve in boiling water, nor even with alkali, which on other occaſions ſo readily diſſolves it; but when mixed with a triple quantity of ſalt of tartar, a great effervеſcence enſued; the produce was a neutral ſalt reſembling that formed by the direct union of the acid and alkali.

965. Properties of the acid obtained by nitre.

The earth of molybdæna, procured by nitre, requires much leſs water for its ſolution; it does not expel the acid from vitriolated tartar; is more eaſily fuſed, and does not ſublime in an open crucible. When fuſed with charcoal-powder, it affords a ſolution with water, containing a neutral ſalt, which precipitates all others. The reaſon of theſe differences is, that it contains a portion of alkali, though it be ever ſo frequently purified by ſolution and cryſtallization. That this is the caſe we know from the following experiments: 1. If to a ſolution of the nitrous earth of molybdæna we add ſome nitrous acid, the latter attacks the alkali, and the greateſt part of the diſſolved earth is precipitated. This, however, does not happen, except by long boiling. 2. The neutral ſalt obtained by fuſion proves the ſame. This neutral ſalt is produced in the following manner. The earth which contains

Acid of molybdæna and its combinations.

tains only a ſmall quantity of alkali operates as an acid, as appears from its changing the colour of lacmus to red; but the alkali prevents as much earth from entering into it as is neceſſary to its ſaturation with phlogiſton; for the acid of molybdæna has a greater attraction for alkali than for phlogiſton. The charcoal which remains after lixiviating the compound of acid of molybdæna and charcoal, yields vapours in an open crucible, and gives a ſublimate containing the phlogiſticated earth of manganeſe. This alkali fixes the earth in the open air; and hence we ſee alſo the reaſon why this earth does not expel the acid from vitriolated tartar; for its attraction for the alkali muſt diminiſh in proportion as it comes nearer the point of ſaturation; and as the pure earth contains no alkali, it attracts a little from the vitriolated tartar; and conſequently there can appear but a ſlight veſtige of vitriolic acid. This ſmall quantity of acid likewiſe occaſions its more eaſy ſolubility in water.

966 Molybdæna recompoſed by uniting its acid with ſulphur.

The pure acid of molybdæna recompoſes that ſubſtance by being combined with ſulphur. Mr Scheele having mixed ſome very fine powder of this earth with three parts of ſulphur, and committed the mixture to diſtillation in a glaſs retort, the receiver was filled with the ſuperfluous ſulphureous vapours, which had alſo the fetid ſmell of volatile ſpirit of ſulphur. In the retort a black powder remained, which on every chemical trial was found to be a true molybdæna; ſo that there is now no doubt of this ſubſtance being compoſed of a particular kind of acid united to ſulphur.

§ 14. *Of the Acid of* LAPIS PONDEROSUS, TUNGSTEN, *or* WOLFRAM.

967 This ſubſtance conſidered as a metallic earth by Mr Bergman.

THIS ſubſtance has been analyſed both by Mr Scheele and Mr Bergman, though the former has the merit of diſcovering the acid contained in it; which the latter conſiders, as well as the earth of molybdæna, not as truly acid, but as metallic earths. Mr Scheele's experiments for analyſing this ſubſtance were as follow:

968 Scheele's method of analyſing it.

1. On one part of finely powdered tungſten were poured two parts of concentrated acid of vitriol. By diſtillation the acid paſſed over unchanged; the reſiduum, which was of a bluiſh colour, after being boiled for a ſhort time, and the liquor filtered off, depoſited ſome vitriolated lime or gypſum by ſtanding. 2. Twelve ſcruples of common nitrous acid, or pure aquafortis, being poured on two of finely powdered tungſten, no effervescence enſued; but on expoſing the mixture to a ſtrong digeſting heat, it aſſumed a citron yellow colour. The acid was then poured off into another phial, and the yellow powder edulcorated with water. 3. On this yellow powder eight ſcruples of cauſtic volatile alkali were poured, and the phial expoſed to heat; on which the yellow colour inſtantly vaniſhed, and the powder became white. This ſolution was in like manner put into a ſeparate phial, and the powder edulcorated; and as the matter was ſenſibly diminiſhed by theſe operations, they were alternately repeated, till at length the whole was diſſolved, excepting three grains, which ſeemed to be ſiliceous earth. The ſame effects enſued on treating this ſubſtance with muriatic acid, only the ſolution was of a deeper yellow colour. 4. The ſolutions made in the foregoing manner with nitrous acid being all mixed together, ſome drops of phlogiſticated alkali were added; by which about three grains of Pruſſian blue were precipitated. 5. The mixture was then ſaturated with cauſtic volatile alkali; but as no precipitate appeared, a ſolution of fixed alkali was added, which threw down two ſcruples and five grains of white earth of a mild calcareous kind. On adding ſome nitrous acid to the extracts made by volatile alkali, a white powder was precipitated, which, on edulcoration, proved to be the true acid of tungſten.

Acid of lapis ponderoſus and its combinations.

969 Effects of heat upon it.

On treating tungſten with a ſtrong heat in the dry way, the following appearances took place: 1. One part of tungſten mixed with four of alkali of tartar was melted in an iron crucible, and then poured out on an iron plate. Twelve times its weight of boiling water being then poured upon it, a white powder ſubſided to the bottom, which diſſolved in a great meaſure in nitrous acid. 2. The undiſſolved part of the powder was tried; and being again mixed with four parts of alkali, was melted as before: and the maſs being alſo diſſolved in water, and nitrous acid poured on the reſiduum, only a very ſmall portion of grey powder was left undiſſolved. 3. The ley being ſaturated with nitrous acid, grew thick by the precipitation of a white powder; which was afterwards waſhed with cold water and dried, and then proved to be the ſame acid of tungſten with that already deſcribed. The ſolution in nitrous acid precipitated with fixed alkali gave a white precipitate, which was found to be calcareous earth.

970 Its chemical properties.

The properties of the acid of tungſten are, 1. Under the blow-pipe it became firſt of a reddiſh yellow colour, then brown, and at laſt black. It neither ſmoked nor gave any ſigns of fuſion. 2. With borax it produced a blue, and with microcoſmic ſalt, a ſea-green glaſs. 3. Boiled with a ſmall portion of the nitrous or marine acids, the powder becomes yellow, and with the acid of vitriol bluiſh. 4. On ſaturating a ſolution of the acid with fixed alkali, a neutral ſalt in very ſmall cryſtals is obtained. 5. With volatile alkali this acid forms an ammoniacal ſalt, ſhaped like the points of ſmall pins. On diſtillation the alkali ſeparates in a cauſtic ſtate, the acid remaining behind in the retort in form of a dry yellow powder. On mixture with a ſolution of lime in ſpirit of nitre, a double elective attraction takes place, the acid of tungſten uniting itſelf with the lime, and that of nitre with the volatile alkali. 6. With magneſia the acid of tungſten forms a ſalt very difficult of ſolution. 7. It produces no change on ſolutions of alum or lime, but decompoſes a ſolution of terra ponderoſa in acetous acid, and the compound is totally inſoluble in water. 8. It precipitates of a white colour ſolutions of iron, zinc, and copper, in the vitriolic acid; ſilver, quickſilver, and lead, in that of nitre; and lead in the acid of ſea-ſalt. Tin combined with the ſame acid is thrown down of a blue colour; but corroſive ſublimate and ſolutions of gold undergo no change. 9. On calcining the acid of tungſten in a crucible, it loſes its ſolubility in water. 10. It turns black by calcination with inflammable matters and with ſulphur, but in other reſpects continues unaltered. 11. Solution of hepar ſulphuris is precipitated of a green colour by this acid, and the phlogiſticated alkali white; the latter precipitate being ſoluble in water. On the addition of a few drops of muriatic acid to a ſolution of the acid

Acid of lapis ponderosus and its combinations.

acid of tungsten in water, and spreading the liquor on polished iron, zinc, or even tin, it acquires a beautiful blue colour; and the same thing happens when these metals are put into the acid. 12. It differs from the acid of molybdæna in not being volatile in the fire;

971 Differences betwixt the acid of tungsten and molybdæna.

in having little attraction for phlogiston or sulphur; in turning lime yellow, and forming an insoluble compound with it as well as with ponderous earth. It has also a stronger attraction for lime than the acid of molybdæna; for if a combination of lime and acid of molybdæna be digested in a solution of the ammoniacal salt formed by uniting the acid of tungsten with volatile alkali, the latter expels the former, and produces regenerated tungsten. 13. By uniting the acid of tungsten to a calcareous earth, a regenerated tungsten is constantly procured.

972 Bergman's opinion concerning the acids of tungsten and molybdæna.

Mr Bergman observes, that the acid earth of tungsten is nearly allied to that of molybdæna; and both are in a state much resembling that of white arsenic. "It is well known (says he) that arsenic, in its semimetallic state, is nothing but a peculiar acid saturated with phlogiston; and that the white calx is an intermediate state between acid and metal, containing just phlogiston enough to coagulate the acid, but remaining still soluble in water, and showing signs of acidity. If a conclusion from analogy be admissible, all the other metals should consist in a combination of the same nature of the different radical acids, which with a certain quantity of phlogiston are coagulated to a dry earthy substance; and on full saturation are reduced to the state of complete metals."

973 Why he supposed the acids to be metallic earths.

The reasons which induced Mr Bergman to suppose that the acids in question are metallic earths, are as follow: 1. They both show a striking resemblance to white arsenic in form, in producing effects like acids, and in their difficult solubility in water. 2. Their specific gravity; that of arsenic being 3750, the earth of molybdæna 3460, and the acid of tungsten 3000. 3. Their precipitation with phlogisticated alkali; a property hitherto deemed peculiar to metallic calces. Arsenic also, properly dissolved in muriatic acid, gives, with the phlogisticated alkali, a precipitate soluble in water, in the same manner as the acid of tungsten. 4. From their property of tinging vitreous matters; which, as well as that of precipitating with the phlogisticated alkali, is reckoned to be a peculiar property of metals. The acid of tungsten produces by itself some effervescence with mineral alkali. With microcosmic salt it produces a globule at first of a light blue; more of the acid makes it a dark blue; but still it remains free from redness by refraction. A farther addition makes it brown. Borax requires a slight tinge of blue, and with more of the acid becomes of a yellowish brown colour; but remains transparent, provided no farther addition be made. This ultimate brown colour cannot be driven off either by nitre or the point of the flame urged by a blow-pipe. Acid of molybdæna is no less powerful; for with microcosmic salt it produces a beautiful green colour: borax well saturated with it appears grey when viewed by the reflected rays, but of a dark violet by the refracted.

§ 15. *Of the Acid of* Milk.

It is universally known, that in the summer-time milk grows sour and thick in a few days, and that this sourness continues for some time to increase. It is strongest after a fortnight has elapsed; after which, if the whey be filtered and evaporated to one-half the quantity, a few curds will still settle to the bottom.

Acid of milk and its combinations.

974 Milk most strongly acid after standing a fortnight.

By saturating the whey with volatile alkali, a small quantity of animal earth precipitates; and the same thing takes place on the addition of lime-water. On the addition of a small quantity of acid of tartar, the latter soon becomes partially saturated with vegetable alkali, and is converted into tartar.

975 Component principles of sour whey.

Thus the acid of milk besides its proper acid part, contains animal earth and vegetable alkali in a loose state, and which is attracted by the acid of tartar; besides all these it has also a small quantity of the same alkali saturated with muriatic acid. It is no easy matter to separate these substances from one another; because the acid is not sufficiently volatile to rise in distillation by a gentle heat, nor are its principles sufficiently fixed to bear the action of a strong fire. With the one therefore it remains almost entirely in the retort, and with the other it is destroyed. Mr Scheele therefore used the following process.

976 Scheele's method of procuring the pure acid of milk.

He evaporated sour whey till only one-eighth part remained; when the cheesy part being totally separated, he strained the acid; and in order to obtain the animal earth, saturated the liquor with lime, diluting the solution with a triple quantity of water. In order to separate the lime, he employed the acid of sugar, which has a stronger attraction than any other for lime. This earth therefore being separated, the matter was evaporated to the consistence of honey, and highly rectified spirit of wine poured upon it to dissolve the acid part; which being accomplished, the other saline substances were left by themselves: and, lastly, the acid solution being diluted with pure water, and the spirit separated by distillation, the pure acid remained in the retort.

977 Properties of this acid.

The properties of the acid of milk are, 1. Evaporated to the consistence of a syrup, it yields no crystals; and when evaporated to dryness, it deliquesces. 2. By distillation it yields first water, then a weak acid like spirit of tartar; afterwards some empyreumatic oil, with more of the same acid, fixed air, and inflammable air; in the retort was left a fixed coal. 3. By saturation with fixed vegetable alkali it yields a deliquescent salt, soluble in spirit of wine. 4. A salt of a similar kind is obtained by combining it with mineral alkali. 5. With volatile alkali a deliquescent salt is produced, which by distillation yields a great deal of its alkali before the acid is destroyed by heat. 6. It forms deliquescent salts with terra ponderosa, lime, and clay; but with magnesia it forms small crystals, which, however, are again deliquescent. 7. It has no effect either by digestion or boiling on bismuth, cobalt, regulus of antimony, tin, quicksilver, or gold. However, after digestion with tin, it precipitated gold from its solution in aqua-regia, in the form of a black powder. 8. It dissolves iron and zinc, producing inflammable air during the solution. The liquor produced by the dissolution of iron was brown, and yielded no crystals; but the solution of zinc crystallizes. 9. Copper dissolved in this acid communicates to the liquor first a blue, then a green, and then a dark blue colour, without crystallizing. 10. Lead was dissolved after some

Acid of milk and its combinations.

some days digestion; the solution had a sweet astringent taste, and would not crystallize. A small quantity of white matter fell to the bottom, which on examination was found to be vitriol of lead.

978
It seems to be of the acetous kind.
"From these experiments (says Mr Scheele) it appears, that the acid of milk is of a peculiar kind; and though it expels the vinegar from the acetated vegetable alkali, yet it seems destined, if I may so speak, to be vinegar; but from the want of such substances as, during fermentation, produce some spirituous matter, it seems not to be volatilized, though a portion of it indeed arrives at this point, and really becomes vinegar: for without a previous spiritous fermentation, or without brandy, there never arises any vinegar. But that the milk enters into a complete fermentation though there be no sign of brandy present, appears from the following experiment: If a bottle full of fresh milk be inverted into a vessel containing so much of the same liquor that the mouth of the bottle reaches below the surface of the latter, and if you expose this bottle to a degree of heat a little greater than our summer, you will find, in the space of 24 hours, that the milk is not only coagulated, but in part expelled out of the bottle; and that in a couple of days afterwards, the aerial acid extricated from the milk will have expelled the greater part of it. It was said above, that the acid of milk cannot be converted into vinegar, from the want of such substances as during fermentation produce brandy; which appears to be evident from this: If to a kanne of milk you add five spoonfuls of good brandy, and expose the vessel, well corked, in such a manner, however, that you now and then give vent to the air developed during fermentation, you will find in a month, sooner or latter, that the whey will be changed into good vinegar, which, strained through a cloth, may be kept in bottles."

979
Milk capable of complete fermentation.

2d 979
Converted into vinegar.

980
Acid of sugar of milk how procured.
The acid of sugar of milk is considerably different from that just now described. To procure it, Mr Scheele poured 12 ounces of diluted nitrous acid on four ounces of finely powdered sugar of milk contained in a glass retort, to which a receiver was adapted. The retort was placed in a sand-bath, and as soon as the mixture acquired a certain degree of heat, it began to effervesce violently; for which reason, the retort and receiver were taken away from the fire. The mixture, however, continued to grow hotter and hotter, with a great emission of dark red vapours continually increasing, for half an hour. A considerable quantity of nitrous air and aerial acid were extricated during that time. Care must be taken, therefore, to have the retort and receiver both of a sufficient size, and not to make the luting too tight. When the effervescence had subsided, the retort was again placed in the sand-bath, and the nitrous acid thus distilled off till the mass acquired a yellowish colour; on which the retort was immediately taken away from the fire. In two days time the solution seemed to have undergone no remarkable change, nor was there any appearance of crystals. Eight ounces more of the same nitrous acid were therefore added, and the whole exposed to the same degree of heat as before. When the mass grew warm, another effervescence, though weaker than the former, ensued; the yellow colour disappeared, and the nitrous acid was again abstracted, till the solution, which had been rendered opaque by the appearance of a white powder in it, assumed a yellowish colour, on which the retort was again removed from the sand. After it was grown cool, the mass in the retort was found to be inspissated; it was redissolved in eight ounces of water, and filtered. Seven and a half drachms of white powder remained on the filter; the solution which passed through the filter was very acid. It was evaporated to the consistence of a syrup, four ounces more nitrous acid poured upon it, and the evaporation repeated in a sand-heat. After the whole was cool, some small long acid crystals were found, together with a small quantity of white powder which was separated from it, and some more nitrous acid poured on the remaining mass, and on evaporation, more such crystals made their appearance. The same process was repeated several times; by which means the whole mass was at last changed into such crystals, and weighed about five drachms, showing in every respect the same phenomena produced by acid of sugar. The white powder, weighing seven and a half drachms, was the true acid of sugar of milk; and its properties are, 981

Properties of this acid.
1. It burns in a red hot-crucible like oil, without leaving behind it any mark or ashes. 2. It dissolves in boiling water in the proportion of one of salt to 60 of the liquid. 3. One fourth part of the dissolved powder separates from the liquid on cooling, in form of very small crystals. 4. Half an ounce of the salt was dissolved in a glass vessel in 30 ounces of boiling water, and the solution filtered when cold. It had a sourish taste, reddened the tincture of lacmus, and effervesced with chalk. 5. Two drachms of the salt exposed to an open fire in a glass retort, melted, grew black, and frothed very much; a brown salt was found sublimed into the neck of the retort, which smelled like a mixture of salt of benzoin and salt of amber, eleven grains of coal remaining in the retort. The receiver contained a brown liquid without any mark of oil, smelling like the sublimed salt. It contained also some of the salt dissolved, which was separated from it by a gentle evaporation. The sublimed salt weighed 35 grains, had a sour taste, and was easily soluble in spirit of wine, but with more difficulty in water, and burned in the fire with a flame. 6. Concentrated vitriolic acid, distilled with this salt, became very black, frothed much, and decomposed the salt entirely. 7. Acid of sugar of milk, gradually added to a hot solution of alkali, occasioned an effervescence and coagulation in consequence of the formation of a vast number of crystals, which require eight times their weight of water to dissolve them, and separate again in a great measure from the liquid on cooling. The same phenomena took place with the mineral alkali, only the salt was somewhat more soluble, requiring only five times its weight of water for solution. If to a solution of it a solution of alkali of tartar be added, a number of small crystals will soon be formed at the bottom of the vessel, on account of the greater attraction of this acid with the vegetable alkali. 8. With volatile alkali it forms a kind of sal ammoniac, which, after being gently dried, has a sourish taste. By distillation, the volatile alkali is first separated, the lime-water precipitates, and the residuum yields the same products by distillation as the pure acid. 9. With all the earths, acid of sugar of milk forms insoluble salts.

Lithiſiac acid and its combinations.

ſalts. If a ſolution of ponderous earth in muriatic or nitrous acid be dropped into a ſolution of acid of ſugar of milk, the former is inſtantly decompoſed, and the earth falls to the bottom in combination with the acid of ſaccharum lactis. The ſame phenomena take place with ſolutions of lime in the nitrous and marine acids; but ſolution of gypſum is not decompoſed. The ſame alſo takes place with ſolutions of magneſia in vegetable or mineral acids, and with earth of alum; all of which are decompoſed by the neutral ſalts abovementioned. 10. The ſolution of this acid, by reaſon of the ſmall quantity diſſolvable in water, has no ſenſible effects on metals in their perfect ſtate; but when they are reduced to calces, it then acts upon them, and forms ſalts, very little or not at all ſoluble in water. Silver, mercury, and lead are precipitated in form of a white powder; blue, green, and white vitriol, as well as manganeſe combined with acid of vitriol, are not precipitated; but all metallic ſolutions are precipitated by the neutral ſalts.

§ 16. *Of the* Lithisiac *Acid, or Acid of the human Calculus.*

982 Calculi all of the ſame nature.

The calculi examined by Mr Scheele, with a view to diſcover their conſtituent parts, were, as he informs us, all of the ſame nature, whether flat and poliſhed, or rough and angular. A ſmall quantity of calculus in powder was put into a retort, and ſome diluted vitriolic acid, poured upon it. The powder was not affected by a digeſting heat; however, it was diſſolved when the humidity was abſtracted by diſtillation. After the diſſipation of the acid, a black coal was left in the retort, and the vitriolic acid which had paſſed into the receiver was become ſulphureous. The marine acid, whether diluted or concentrated, had no effect upon the calculus, not even when boiled with it. The nitrous acid diluted, or aquafortis, had ſome effect on the calculus, even when cold. On the application of heat, an effervescence enſued with red vapours, and the calculus was diſſolved. Repeating the experiment in a retort with lime-water, the latter was precipitated. The ſolution of calculus is acid, though the menſtruum be boiled with a ſuperabundant quantity of

983 Properties of the acid of calculus.

powder, ſo that there may remain a portion of it undiſſolved. It produces deep red ſpots on the ſkin in half an hour after it is applied; and if the ſaturated ſolution be a little more evaporated, it aſſumes of itſelf a blood-red colour, which however, diſappears on dropping in a ſingle drop of nitrous acid. Terra ponderoſa is not precipitated by it from the muriatic acid; nor are metallic ſolutions ſenſibly changed. With alkalies it becomes ſomewhat more yellow when the alkali is ſuperabundant. The mixture, in a ſtrong digeſting heat aſſumes a roſe colour, and ſtains the ſkin in the ſame manner, without any ſenſation of burning. The mixture likewiſe precipitates metals of different colours; vitriol of iron, black; of copper, green; ſolution of ſilver, grey; corroſive ſublimate, zinc, and lead, of a white colour. Lime water precipitates a white powder ſoluble in muriatic and nitrous acids without effervescence; and though there be an exceſs of precipitated powder, the ſolution will be acid. This white powder, therefore, is the acid of the calculus itſelf, the exiſtence of which is alſo confirmed by Mr Bergman's experiments. The further analyſis of this is related under the article Calculus, below.

Flowers of benzoin, &c.

§ 17. *Of the* Flowers *of* Benzoin, *Acid of* Lemons, *with other anamolous vegetable acids, and the reſemblance which the vegetable acids in general bear to one another.*

984 Flowers of benzoin obtained by ſublimation.

It has long been known, that the reſinous ſubſtance, improperly called gum benzoin, yields by ſublimation with a gentle heat a quantity of fine ſaline matter of a moſt agreeable odour, and ſlightly acid taſte, called *flowers* of *benzoin*. Another method of obtaining

985 By lixiviation.

this ſubſtance is by lixiviating the gum with water, and cryſtallizing the ſalt. Mr Scheele, determined to try what quantity of the flowers could be obtained

986 Quantities obtained by both methods.

from the reſin, found that, by ſublimation, he was able to obtain from one pound of benzoin between nine and twelve drachms of flowers. By lixivation the quantity obtained was conſiderably leſs than the former, owing to the ſaline particles being ſo much covered by the reſin, that the water could not have ſufficient acceſs to diſſolve them all. It was next attempted to procure all the flowers which the benzoin was capable of yielding.

987 Attempts to procure all the flowers the reſin is capable of yielding.

This was firſt done by boiling pounded chalk and benzoin in water, and then filtering the decoction; but no cryſtals appeared. On pouring ſome drops of vitriolic acid into the liquor, the ſalt of benzoin ſoon afterwards precipitated (for this ſalt, which is an acid, was united to the chalk); but the quantity of ſalt was no greater than that obtained by lixiviation.

988 Boiling with chalk inſufficient;

Alkaline ley was next tried, and the ſolution ſaturated with an acid. Thus the ſalt of benzoin was obtained by precipitation; but here this inconvenience was met with, that the powder of benzoin ran together during the boiling, and floated on the ſurface like a tenacious reſin.

989 And with alkaline ley.

990 Boiling with lime the beſt method.

One only method, therefore, remained to be tried, and that was to boil the benzoin with quick-lime; and as the particles of lime, by interſperſing themſelves betwixt thoſe of the benzoin would prevent their running together, and lime has likewiſe the property of acting upon the reſinous particles, this ſeems to be the beſt method of procuring the flowers of benzoin in the greateſt quantity, and alſo of the beſt quality; and thus we may obtain from 12 to 14 drachms of flowers from a pound of benzoin.

991 Mr Scheele's receipt for preparing the flowers of benzoin by this method.

Mr Scheele's receipt for preparing them after this new method, is as follows: "Pour 12 ounces of water upon four of unſlaked lime, and after the ebullition is over, add eight pounds (of 12 ounces each) of water; put then a pound of finely powdered reſin of benzoin into a tinned pan, pour upon it firſt about ſix ounces of the lime-water abovementioned; mix them well together, and thus add all the reſt of the lime-water in ſucceſſion. The reaſon of adding the lime water thus by portions, is, that if it be poured in all at once, it will not mix with the benzoin, which will likewiſe coagulate and run together into a maſs. This mixture muſt be boiled over a gentle fire for half an hour, agitating it conſtantly; then taking it from the fire, let it ſtand quiet for ſome time to ſettle, after which the clear liquor is to be poured off into a glaſs veſſel. Pour then eight pounds of water more upon the lime in the veſſel, and uſe this lime-water as before, repeating this proceſs twice more, making four times in

Flowers of benzoin, &c.

in all; and lastly, putting all the residuum together on a filter, pour hot water upon them. During this process, the calcareous earth of the lime-water combines with the acid of benzoin, and separates it from the resinous particles of this substance; but a small quantity of resin is dissolved by the lime-water, and gives it a yellow colour.

"All these liquors being mixed together and boiled down to two pounds, are then to be strained into another glass vessel. They are inspissated so far, because the superfluous water would hold a great quantity of the salt in solution; and a little of the resin being soluble in a large quantity of lime-water, but not in a small, falls to the bottom on the liquor being inspissated. When the liqour has become cold, after being strained the last time, add muriatic acid till the flowers be totally precipitated, which happens by reason of the stronger attraction of the marine acid for the calcareous earth. The precipitated coagulum is then to be put upon a filter; and, after being well dried, to be edulcorated sufficiently, by repeatedly pouring cold water upon it, when it must be dried with a gentle heat. As the water made use of for this purpose, however, is capable of dissolving a little of the salt of benzoin, it ought to be evaporated, and afterwards set to crystallize. In order to give this salt a shining appearance, let it be dissolved in a sufficient quantity, six, ounces, for instance, of water by gentle boiling; then strain it immediately, while yet warm, through a cloth, into a glass vessel which has been heated before; and thus a number of fine crystals will shoot as soon as the solution is grown cold. The water is then to be strained from the crystals, and the rest of the salt suspended in the water may be obtained by repeated evaporation and crystallization. In this method, however, a great quantity of the flowers are lost by reason of their volatility; it will therefore be more convenient to keep them in the form of their original precipitate, which is always in fine powder. Cloth answers best for the filtration of the hot solution: when blotting paper is used, the salt sometimes crystallizes in the filter, and obstructs it. The filteration itself might be omitted, were it not that about two grains of resin of benzoin remain united to the liquor, from whence it cannot be separated but by the operation just mentioned."——

992 Flavour of the flowers may be taken away and produced at pleasure.

The properties of this salt as an acid are but little known. It has a most agreeable flavour; which, however, ceases as soon as it unites with calcareous earth, but is recovered again on being separated by any other acid.

993 Anomalous vegetable acids how divided.

With regard to the other vegetable acids, they may be divided into the essential, the fermented, and empyreumatic.

994 Of the essential acids.

The essential acids are pure, as exemplified in those of lemons, sorrel, and sorrel-dock; or but little altered by the admixture of other matters, as those of cherries, barberries, tamarinds, &c. In sweet fruits they are generally so much covered when ripe as scarce to be distinguished: however, these latent acids become more evident, partly in fermentation, and partly by dry distillation. By the former method, all flowers, excepting a few which bear cruciform flowers, are made to yield vinegar; and by dry distillation only a very few yield a volatile alkali.

995 Empyreumatic acids.

The acid which passes over in dry distillation is scarce perceptible while the subject retains its natural form; but when once produced, has the same essential qualities with the other; whence it was naturally supposed that all vegetable acids are at bottom the same.

996 Whether the acid of sugar or of tartar is the basis of vegetable of acids.

Chemists, however, have been divided in their opinions on this subject; some supposing that the acid of sugar or of tartar is the basis, and others that vinegar is the basis of them all. In proof of this latter hypothesis, it has been urged, that the acid of lemons may be crystallized; of which we have the following account in Scheele's Essays.

997 Dr Crell's method of crystallizing the acid of lemons.

"The juice will not shoot into crystals by mere evaporation, even when thickened to the consistence of a syrup. This our author supposed to proceed from the great quantity of mucilaginous matter with which the juice abounds; for which reason he mixed the inspissated juice with strong spirit of wine which coagulated the whole: but even thus he could obtain no crystals by evaporation. He therefore employed the method used for procuring the pure acid of tartar, and which is formerly described. The lemon juice, while boiling, was saturated with pulverised chalk, and the compound immediately fell to the bottom in a form nearly resembling tartarised lime. To separate the acid, a quantity of oil of vitriol, equal in weight to the chalk employed, but diluted with ten times it weight of water was necessary. This mixture must be boiled in a glass vessel for a few minutes; and when grown cold, the acid is to be separated from the gypsum by filtration. In order to crystallize it, we must evaporate the whole to the consistence of a thin syrup; but great care is to be taken, lest any of the calcareous earth remain in the evaporated liquour: to determine which, a little of it is to tried with fresh oil of vitriol, which will throw drown the remainder: and in this case some more must be added to the whole quantity;

998 The crystallization prevented by the smallest particle of lime.

for the least particle of lime remaining prevents the crystallization, while the superfluous quantity of oil of vitriol, if too much happens to be added, remains in the liquor. The crystals shoot equally well in a hot as in a cold temperature, which is very unusual."

999 Salt of lemons cannot be converted into acid of sugar.

It is very remarkable that this crystallized salt of lemons cannot be converted into acid of sugar by means of that of nitre, though the extract of the juice itself may. Sour cherries afford acid of sugar, and another salt supposed to be tartar; and a kind of sugar may be obtained not only from roots of various kinds, but from fine raisins, and, as Dr Crell thinks, from expressed must; but whether the saccharine acid can be procured from this kind of sugar in equal quantity as from the common, or even whether it yields the same products with common sugar by dry distillation, is still a matter of doubt.

1000 Product of acid of tartar by dry distillation.

Pure acid of tartar yields on distillation *per se* an empyreumatic acid, and a coal consisting of oily particles and calcareous earth. Dr Crell therefore asks, May not the acetous acid be mere acid of tartar, which did not meet with alkaline salt and earth enough with which it might combine and become more fixed; but, on the contrary, attracted more subtile oily particles, and thus become more volatile?

1001 Acetous acid almost entirely destoyed by fire.

In distilling terra foliata tartari in the dry way, the acid of vinegar which enters its composition is almost entirely destroyed, only $\frac{1}{24}$th of pure acid being obtained, the residuum in the retort, as well as the rest of that which comes over into the receiver, being entirely alkakine; and the

same

Identity of the vegetable acids, &c.

ſame thing happens to the acid of tartar, the empyreumatic acid abovementioned being extremely weak. Mr Beaumé likewiſe informs us, that if any calcareous earth, egg-ſhells, for inſtance, be diſſolved in vinegar, and the cryſtallized ſalt be diſtilled, we obtain $\frac{1}{2}$ $\frac{1}{4}$ of a red and very fiery inflammable fluid, ſmelling like empyreumatic acetous ether, which reddens tincture of turnſole. Muſt, diſtilled before fermentation, yields only an empyreumatic acid reſembling ſpirit of tartar. The conjecture therefore ſeems reaſonable, that vinegar and tartar have for their baſis the ſame ſpecies of acid, which in the caſe of vinegar is combined with a greater proportion of oil, and in tartar with more earth.

1002 Requiſites for bringing vinegar nearer the ſtate of tartar.

To bring vinegar therefore nearer the ſtate of tartar, we muſt deprive it of its fine volatilizing phlogiſton, combine it with more fixed matter, and reſtore its groſſer oil. All this, however, is extremely difficult to be effected.

1003 Mr Weſtrumb's unſucceſsful attempt.

Mr Weſtrumb, who attempted it, added nitrous acid in various proportions, but could only produce a phlogiſtication of the latter, and dephlogiſtication of the vinegar; but as he could not think of any method of ſeparating the two acids from one another, he was unable to inveſtigate the properties of vinegar thus dephlogiſticated.

1304 Dr Crell's opinion of the poſſibility of tranſmutation.

Dr Crell is of opinion, that this might have been done by vegetable alkali, lime, and terra ponderoſa. The nitrous acid, with vegetable alkali, would have ſhot into the ordinary hexangular cryſtals of nitre: the acetous acid would have formed a compound not eaſily cryſtallized, provided it had remained unchanged; and, though it had approached the nature of ſaccharine acid, would ſtill have formed a compound difficultly cryſtallizable. The effects of theſe acids, indeed, on lime, are directly oppoſite to what they are on terra ponderoſa. With the former, nitrous acid forms a liquor which can ſcarce be cryſtallized; with the latter it produces ſalts difficult to be diſſolved: while the acetous acid, with terra ponderoſa, forms deliqueſcent ſalts; with lime, ſuch as effloreſce in the air. But if the vinegar, by means of the operation already mentioned, had been made to approach towards the nature of acid of ſugar, tranſparent cryſtals would immediately have fallen by reaſon of the ſtrong attraction of this acid for lime.

1005 Method recommended by him for attempting the experiment.

Dr Crell therefore recommends the following method. Let nitrous acid be ſeveral times diſtilled off from vinegar; and when the former, upon being newly added, produces no more red vapours, ſaturate the liquor with lime or terra ponderoſa, ſeparating the ley, which will not ſhoot, from the cryſtals. The nature of the ſalt which does not contain nitrous acid, may be determined from the figure of its cryſtals, or from the effects of other ſalts in conſequence of a double elective attraction. We might likewiſe add freſh nitrous acid to the ſeparated ſalt, or to the whole mixture, without any ſeparation of the nitrous ſalt, till the earthy ſalt, which does not contain any nitrous acid, be ſaturated. The vinegar, if unaltered by the operation, would riſe on diſtilling the liquor; and if converted into ſaccharine acid, would not be diſlodged from lime by ſpirit of nitre. In like manner, diſtilled vinegar ſhould be ſaturated with chalk, the compound reduced to cryſtals, and then expoſed to as ſtrong a fire as it can bear without expelling the acid, in order to diſſipate ſome phlogiſtic particles. Let it then be diſſolved, filtered, and cryſtallized again; after which it may be treated with nitrous acid as above directed. "Perhaps (ſays Dr Crell), the acetous acid may by this combination acquire more fixity; ſo that the nitrous acid ſhall be able to produce a greater change. Should it paſs over again in the form of acetous acid unchanged, let it be combined once more with calcareous earth; and let the foregoing experiment be repeated, in order to try whether ſome ſenſible change will not enſue. Should this method fail, try the oppoſite; that is, endeavour to add more groſs phlogiſtic matter to the vinegar. Try to combine ſtrong vinegar, and that which has been diſtilled, with unctuous oils. Thus we might perhaps bring it nearer to tartar; and again, by means of nitrous acid, convert it into acid of ſugar.

1006 His attempts to prove that all the vegetable acids may be reduced to one.

In another diſſertation on this ſubject, Dr Crell undertakes to ſhow, that all the vegetable acids may be converted into one, and that this is contained in the pureſt ſpirit of wine. The following are adduced as proofs.

1007 From the reſiduum of dulcified ſpirit of nitre.

1. If the reſiduum of dulcified ſpirit of nitre be boiled with a large quantity of nitrous acid, care being taken at the ſame time to condenſe the vapours by a proper apparatus; and if the liquid which has paſſed over be ſaturated with vegetable alkali, nitre and terra foliata tartari will be obtained; and on ſeparating the latter by means of ſpirit of wine, the vinegar may be had in the ordinary way of decompoſing the ſalt.

2. On boiling the reſiduum over again with nitrous acid, the ſame products are obtained; and the more frequently this proceſs is repeated, the leſs acid of ſugar is procured, until at length no veſtige of it is to be met with.

1008 From the decompoſition of acid of ſugar.

3. Pure acid of ſugar, boiled with 12 or 14 times its quantity of nitrous acid, is entirely decompoſed, and the receiver is found to contain phlogiſticated nitrous acid, vinegar, fixed air, and phlogiſticated air, while a little calcareous earth remains in the retort.

1009 From the production of acid of tartar from the reſiduum of dulcified ſpirit of nitre.

4. Acid of ſugar is likewiſe decompoſed by boiling with ſix times its quantity of vitriolic acid. In the receiver we find vinegar phlogiſticated with vitriolic acid, aërial acid; while pure vitriolic acid remains in the retort.

5. By ſaturating the reſiduum of dulcified ſpirit of nitre with chalk, there is formed an inſoluble ſalt, which by treatment with vitriolic acid yields a real acid of tartar, conſtituting a cream of tartar with vegetable alkali.

1010 From the production of empyreumatic acid of tartar from the liquor in which tartarous ſelenite is boiled.

6. On evaporating the liquor from which the tartareous ſelenite was obtained, a dark-coloured matter remains, yielding on diſtillation an empyreumatic acid of tartar, and a ſpongy coal. Hence it would ſeem, that ſpirit of wine conſiſts of acid of tartar, of water, and phlogiſton; ſo that it is a native dulcified acid: and nitrous acid, on being mixed with it in moderate quantity, diſlodges the acid of tartar. On the addition of more nitrous acid, the acid of tartar is reſolved into acid of ſugar and phlogiſton; and by a ſtill greater addition, the ſaccharine acid is changed into vinegar.

1011 From the ſolution of mangaheſe by nitrous acid and acid of ſugar.

7. On boiling one part of the acid of ſugar with one and an half of mangaheſe and a ſufficient quantity of nitrous

Acid of fat. nitrous acid, the manganefe will be almoft entirely diffolved, and phlogifticated nitrous acid along with vinegar will pafs over into the receiver.

8. On boiling together acid of tartar, manganefe, and nitrous acid, we obtain a folution of the manganefe, with phlogifticated nitrous acid and vinegar as before.

1012 From the folution of the fame with vitriolic acid and that of tartar.

9. If acid of tartar be boiled along with vitriolic acid and manganefe, the latter will be diffolved, and vinegar with vitriolic acid will pafs over into the receiver.

1013 From the digeftion of acid of tartar with fpirit of wine.

10. On digefting acid of tartar and fpirit of wine for feveral months, the whole is converted into vinegar, the air in the veffel being partly converted into cretaceous acid, and partly into phlogifticated air.

11. On boiling fpirit of wine with vitriolic acid and manganefe, it will be converted into vinegar and phlogifticated air.

1014 From the folution of manganefe with vitriolic acid and fpirit of wine.

12. By diftilling fpirit of wine upwards of 20 times from cauftic alkali, it was changed into vinegar, and a confiderable quantity of water was obtained.

1015 From the diftillation of fpirit of wine with cauftic alkali.

Hence it appears, fays Dr Crell, that the acids of tartar, fugar, and vinegar, are modifications of the fame acid, as it contains more or lefs phlogifton. The acid of tartar has the greateft quantity, the acid of fugar fomewhat lefs, and vinegr the leaft of all. In thefe experiments, however, care muft be taken that neither the nitrous acid nor fixed alkali employed contain any marine acid, otherwife the refults will be uncertain.

§ 18. *Of the Acid of Fat.*

2d 1015 How procured.

This may be obtained from fuet by means of many repeated diftillations. A fmall quantity is feparated at each diftillation; but by diftilling the empyreumatic oil into which the fuet is thus converted over and over, a frefh quantity is always obtained. The acid of fat in fome refpects has a refemblance to that of fea-falt; but in others is much more like the vegetable kind, as being deftructible in a ftrong fire, forming compounds which do not deliquefce with calcareous earth, and uniting intimately with oily fubftances.

3d 1015 Its effects on alkalies, &c.

With alkalies it forms falts entirely different from thofe yielded by the other acids; with the volatile alkali, particularly, it produces a concrete volatile falt. When faturated with calcareous earth, it yields brown cryftals; and a falt of the fame kind was obtained by Dr Crell from a mixture of quicklime and fuet diftilled to drynefs, and boiling up the refiduum with water. The cryftals were hexagonal, and terminated by a plane furface; their tafte was acrid and faltifh; they did not deliquefce in the air, and were eafily and copioufly diffolved in water. With magnefia and earth of alum a gummy mafs is obtained, which refufes to cryftallize.

4th 1015 On metals.

With regard to the metals, Dr Crell informs us, that the acid of fat copioufly diffolves manganefe into a clear and limpid liquor. It diffolves the precipitate of cobalt, but not the regulus. White arfenic is acted upon but fparingly, and nickel not at all, though it forms a green folution with the precipitate from nitrous acid. Regulus of antimony, by the affiftance of heat is diffolved into a clear liquor, which became milky in the cold: it cryftallized on evaporation, and did not deliquate in the air. Zinc readily diffolved, and imparted a peculiar metallic tafte, falling to the bottom in the form of a white powder on the addition of an alkali. Bifmuth in the metallic ftate was not diffolved; but the precipitate was. It acted upon mercury after being twice diftilled from it, and poured afrefh upon the metal. The mercury could not be entirely precipitated by common falt. It acted more vigoroufly upon a precipitate from corrofive fublimate; from the folution of which a white fublimate was obtained after the liquor had been drawn off by diftillation. A gold-coloured folution was obtained from platina by diftilling the acid from it to drynefs, and then pouring it back again; the precipitate of this metal from aqua-regia by fpirit of wine was diffolved in great abundance. Iron was very eafily diffolved in it, and exhibited a liquor of an aftringent tafte, which fhot into needle-like cryftals that did not deliquefce in the air. Lead was corroded and rendered the acid turbid. Minium was converted into a white powder, and then diffolved with greater eafe. The folution has a fweet tafte, and cannot be precipitated by fea-falt. Tin was corroded into a yellow calx, and diffolved but in very fmall quantity. Copper was diffolved, even in the cold, into a green liquor; but the folution was greatly promoted by heat. On evaporation it fhowed fome difpofition to cryftallize, but again attracted moifture from the air. Silver-leaf was attacked only in a very fmall degree; however, fome was precipitated by means of copper, and the marine acid rendered the liquor turbid. The calx precipitated from aquafortis was diffolved more copioufly. Silver was precipitated of a white colour from aquafortis by the pure acid itfelf, as well as by its ammoniacal falt. Half an ounce of the acid diftilled four times almoft to drynefs from fome gold-leaves, and at length poured back upon them, the precipitate of a dilute folution of tin obtained by it, gained only a faint colour, rather inclining to red; but a mixture of two parts of acid with one of aquafortis, diffolved gold very readily.

Fixed alkaline falts and their combinations.

§ 19. *Of Fixed Alkaline Salts.*

1016 How procured.

Of thefe there are two kinds; the vegetable and mineral. The former is never found by itfelf, and but rarely in combination with any acid; but is always prepared from the afhes of burnt vegetables. It is got in the greateft quantity from crude tartar; from which, if burned with proper care and attention, we may obtain one pound of alkali out of $2\frac{1}{4}$ of the tartar. The latter is found native in fome parts of the earth. It is likewife found in very large quantities combined with the marine acid, in the waters of the ocean, and in the bowels of the earth; thus forming the common alimentary falt. It is alfo produced from the afhes of certain fea-plants, and of the plant called *kali;* from whence both the mineral and vegetable alkalies have taken their name.

1017 Vegetable alkali cryftallized.

The vegetable alkali difficultly affumes a cryftalline form; neverthelefs, it may be partially united with fome acids in fuch a manner as to cryftallize, and lofe its property of deliquating in the air, without at the fame time ceafing to be an alkali. Of this we have an example in the acid of ants abovementioned. Something

Fixed alkaline ſalts and their combinations.

thing of the ſame kind we have obſerved in treating vegetable fixed alkali with ſpirit of wine. A gallon of pretty ſtrong ſpirit of wine being drawn over from a pound of ſalt of tartar, a black unctuous liquor was left, which ſhot into cryſtals very much reſembling vitriolated tartar, and which did not deliquate in the air, but were nevertheleſs ſtrongly alkaline. Dr Black, however, informs us, that the vegetable alkali may be ſhot into fine cryſtals; but which cannot be preſerved, on account of their great attraction for moiſture, unleſs cloſely ſhut up from the air. They have not ſuch a quantity of water as to undergo the aqueous fuſion.

The mineral alkali in its natural ſtate always aſſumes a cryſtalline form, ſomewhat reſembling that of ſal mirabile. It does not deliquate in the air, nor does it ſeem to have ſo ſtrong an attraction for water, even when in its moſt cauſtic ſtate, as the vegetable alkali: hence mineral alkali is preferable to it in making ſoap,

1018 Change on the vegetable alkali.

which is always of a firmer conſiſtence with mineral than with vegetable alkali. If vegetable alkali is combined with ſpirit of ſalt, ſome change ſeems to be thereby induced upon it; as the ſalt produced by expelling the marine acid by means of the vitriolic, and then cryſtallizing the maſs, cryſtallizes differently from vitriolated tartar. Whether the vegetable alkali might by this means be entirely converted into the mineral, deſerves a further inquiry.

1019 Difference between vegetable and mineral alkalies.

Both mineral and vegetable alkalies, when applied to the tongue, have a very ſharp, pungent, and urinous taſte; but the vegetable conſiderably more ſo than the mineral. They both unite with acids, and form different neutral ſalts with them: but the vegetable alkali ſeems to have rather a greater attraction for acids than the other; although this difference is not ſo great as that a neutral ſalt, formed by the union of mineral alkali with any acid, can be perfectly decompoſed by an addition of the vegetable alkali, unleſs in conſiderable exceſs.

1020 Compoſed of a cauſtic ſalt and fixed air.

Both vegetable and mineral alkali appear to be compoſed of an exceedingly cauſtic ſalt united with a certain quantity of fixed air. This may be increaſed ſo far, as to make the vegetable alkali aſſume a cryſtalline form, and loſe great part of its alkaline properties: but as the adheſion of great part of this air is very ſlight, it eaſily ſeparates by a gentle heat. Some part, however, is obſtinately retained; and the alkali cannot be deprived of it by the moſt violent calcination *per ſe*. The only method of depriving it entirely of its fixed air is, by mixing an alkaline ſolution with quicklime.

Fixed Alkalies COMBINED,

1021 Hepar ſulphuris.

I. *With Sulphur*. The produce of this is the red fetid compound called ***hepar ſulphuris***, or liver of ſulphur. It may be made by melting ſulphur with a gentle heat, and ſtirring into it, while melted, four times its weight of dry alkaline ſalt. The whole readily melts and forms a red maſs of a very fetid ſmell, and which deliquates in the air. If ſulphur is boiled in a ſolution of fixed alkaline ſalt, a like combination will take place.

In this proceſs, when the hepar is made either in the dry or the moiſt way, the fixed air of the alkali is diſcharged, according to Dr Prieſtley's obſervation. Neither does a fixed alkali, when combined with fixed air, ſeem capable of uniting with ſulphur; nor will the union be accompliſhed without heat, unleſs the alkali is already in a cauſtic ſtate. Hence a cold ſolution of hepar ſulphuris may be decompounded, partly at leaſt, by fixed air. On adding an acid, however, the decompoſition takes place much more rapidly; and the ſulphur is precipitated to the bottom, in form of a white powder.

Fixed alkaline ſalts and their combinations.

1022 Decompoſed.

During the precipitation of the ſulphur from an alkali, by means of acids, a thick white ſmoke ariſes, of a moſt fetid ſmell and ſuffocating nature. It burns quietly, without exploſion, on a candle's being held in it. Calces of ſilver, lead, iron, or biſmuth, are rendered black by it. Hence, if any thing is wrote with a ſolution of lead, and a ſolution of hepar ſulphuris is paſſed over it when dry, the writing, formerly inviſible, will immediately appear of a blackiſh brown colour. Silver, in its metallic ſtate, is prodigiouſly blackened either by the contact of this vapour, or by being immerſed in a ſolution of the hepar ſulphuris itſelf. Litharge is inſtantly reſtored to its metallic ſtate, on being immerſed even in a cold ſolution of hepar ſulphuris.

1023 Inflammable vapour in the compoſition of it.

By being united with an alkali, the acid of ſulphur ſeems very much diſpoſed to quit the phlogiſton. If a ſolution of hepar ſulphuris is expoſed to the air for ſome time, it is ſpontaneouſly decompoſed; the phlogiſton of the ſulphur flying off, and the acid remaining united with the alkali into a vitriolated tartar. This decompoſition takes place ſo remarkably, when liver of ſulphur is diſſolved in water, that, by a ſingle evaporation to dryneſs, it will be almoſt totally changed into vitriolated tartar. If this ſubſtance, in a dry ſtate, be expoſed to a moderate degree of heat, and the maſs kept conſtantly ſtirring, a like decompoſition will follow; the phlogiſton of the ſulphur will fly off, and the acid unite with the alkali.

1024 Phlogiſton of ſulphur diſpoſed to quit the acid.

Liver of ſulphur is a great ſolvent of metallic matters; all of which, except zinc, it attacks, particularly in fuſion. It ſeems to diſſolve gold more effectually than other metals. This compound alſo diſſolves vegetable coals, even by the humid way: and theſe ſolutions, if ſuffered to ſtand in the open air, always precipitate a black powder, no other than the coal they had diſſolved, in proportion to the quantity of hepar ſulphuris decompoſed. When vegetable coal is thus diſſolved by liver of ſulphur in fuſion, it is of a much deeper red than in its natural ſtate. The ſolution in water is of a green colour.

1025 Metals and charcoal diſſolved by it.

II. *With Expreſſed Oils*. The reſult of this combination is *ſoap*; for the preparation of which in large quantities in the way of trade, ſee SOAP. The ſoap which is uſed in medicine is prepared without heat, in the following manner, according to the author of the Chemical Dictionary.

1026 Soap.

"One part of quicklime, and two parts of good Spaniſh ſoda (the ſalt prepared from the aſhes of the herb kali), are boiled together during a ſhort time in an iron caldron. This lixivium is to be filtered, and evaporated by heat, till a phial, capable of containing an ounce of water, ſhall contain an ounce and 216 grains of this lixivium. One part of this lixivium is to be mixed with two parts of oil of olives, or of ſweet almonds, in a glaſs or ſtone-ware veſſel. The mixture ſoon becomes thick and white; and muſt be ſtirred from time to time with an iron ſpatula. The combination

Fixed alkaline salts and their combinations. nation is gradually completed, and in seven or eight days a very white and firm soap is obtained."

In attempting combinations of this kind, it is absolutely necessary that the alkali be deprived of its fixed air as much as possible; otherwise the soap will be quite unctuous and soft: for fixed alkalies have a greater attraction for fixed air than for oil, and hence soap is decompounded by blowing fixed air into a solution of it in water. It may be made either with tallow, wax, spermaceti, butter of cocoa, the coarser resinous substances, or animal oils.

1027 Starkey's soap. III. *With Essential Oils*. The volatility of these oils in a great measure hinders them from being acted upon by alkalies: nevertheless, combinations of this kind have been attempted; and the compounds so produced have been called *Starkey's soap*, from one Starkey a chemist, who endeavoured to volatilize salt of tartar by combining it with oil of turpentine. His method was to put dry salt of tartar into a matrass, and pour upon it essential oil of turpentine to the height of two or three fingers breadth. In five or six months, a part of the alkali and oil were combined into a white saponaceous compound. This must be separated from the mixture, and more of it will afterwards be formed by the same method.

Chemists, imagining this soap to be possessed of considerable medical virtues, have endeavoured by various methods to shorten this tedious process. Of these one of the most expeditious is that recommended by Mr Beaumé; which consists in triturating, for a long time, alkaline salt upon a porphyry, and adding oil of turpentine during the trituration. According to him, the thick resinous part of the oil only can combine with the salt; and, during the time this combination is effected, the more subtile and attenuated parts will fly off. Hence he finds that the opeartion is considerably abridged by the addition of a little turpentine or common soap. The most expeditious of all, however, is that mentioned by Dr Lewis; which consists in heating the alkali red hot, and then throwing it into oil of turpentine, stirring them well together; on which they immediately unite into a saponaceous mass.

This kind of soap is subject to great alterations from keeping; particularly the loss of its colour, and a kind of decomposition occasioned by the extraction of an acid from the oil of turpentine, which unites with the alkali, and crystallizes not only all over the surface, but in the very substance of the soap. The nature of this salt is unknown, but certainly deserves consideration.

1028 Phlogisticated alkalies. IV. *With Phlogiston*. This combination is effected by calcining them with the charcoal either of vegetable or animal matters. The consequence is, that they are greatly altered in their properties; sometimes so much as to be enabled to precipitate calcareous earths from their solutions in acids. Metallic solutions precipitated by them in this state, assume different colours.

Differences observed between Fixed Alkalies obtained from different *Vegetables*.

These differences we must conceive to arise from some proportion of the oily and phlogistic matter of the vegetable remaining in the ashes from whence the salts are extracted; for when reduced to their utmost purity, by repeated calcinations in a strong fire, and deliquations in the air, all of them, the marine alkali excepted, appear to be the very same.

1029 Mr Gmelin's experiments. On this subject Mr Gmelin has given a great number of experiments in the fifth volume of the *Commentaria Petropolitana*; and found very considerable differences, not only between the alkaline salts, but likewise the pure vegetable earths obtained from different vegetables by burning. The salts of the several plants examined were prepared with great care, and all of them exactly in the same manner; each vegetable being burnt in a separate crucible, with the same degree of fire, till no remains of coaly matter could any longer be perceived; and the ashes elixated in glass vessels with cold distilled water. The salts, thus obtained, were found to produce different colours on mixture with certain liquors, and to effervesce in very different degrees with acids: certain metallic solutions were by some precipitated, by others only rendered thicker, by others both precipitated and rendered thick; whilst some occasioned neither the one nor the other of these changes, but left the fluid clear and transparent. Thus, with the vitriolic acid, the salts of southernwood and sage struck a pale brown colour; those of pine-tops and rue, a yellow; that of fern, a reddish yellow; and that of sanicle, a dark leek-green: that of dill yielded a leek-green precipitate, with elegant green flakes floating in the liquor. This last salt also gave a greenish precipitate with the marine acid, and a red one with the nitrous. Solution of corrosive sublimate was changed yellow by salt of southernwood; of a brownish colour, by that of colt's-foot; of a deep red, by that of wormwood; and of a pitch-colour, by that of dill. That of fern threw down an opal-colour; of sage, a sulphur-yellow; of elder flowers, a citron yellow; of sanicle, a saffron colour; and of milfoil, a deep-red precipitate. From solution of silver, salt of *carduus benedictus* threw down a white; of camomile, a grey; of hyssop, a brownish; of dill, a blackish brown; of scabious, a yellowish; and that of pine-tree tops, a sulphur yellow precipitate. Solution of vitriol of copper was changed by salt of southernwood to a bright sea-green; by that of dill, to an unsightly green; of agrimony, to a greenish blue; and by that of milfoil, to a bright sky-blue: the salt of penny-royal made the liquor thick as well as blue, and that of feverfew made it thick and green: the salt of hyssop threw down a green precipitate, that of scurvy-grass a blue one, and that of fumitory a greenish blue: whilst the salt of fern made scarcely any change either in the colour or consistency of the liquor.

§ 19. *Of Volatile Alkali*.

1030 Whence obtained. This is a kind of salt obtained from all animal, some vegetable, substances, from soot by distillation with a strong heat, and from all vegetable substances by putrefaction. Though a volatile alkali is procurable from all putrid animal substances by distillation, yet the putrefactive process does not seem to prepare volatile alkali in all of these. Putrid urine, indeed, contains a great quantity of alkali ready formed, whence its use in scouring, *&c.* but the case is not so with putrid blood or flesh. These afford no alkali till after the phlegm has arisen; and this they would

Volatile alkali and its combinations.

would do, though they had not been putrefied. According to Mr Wiegleb, volatile alkali is found in limeftone, lapis fuillus, chalk, marble, coals, turf, loam, clay, and many other kinds of earth. Its exiftence in thefe fubftances may be difcovered merely by diftilling them with a brifk fire, but ftill better by the addition of fome quantity of fixed alkali or quicklime before the diftillation.—It has even been found in all mineral falts and their acids, as vitriol, nitre, common falt, and the acid liquors drawn from thefe fubftances, alfo in gypfum and fulphur: from all which it may be feparated by means of quicklime.—In the vegetable kingdom it is produced by dry diftillation from muftard-feed, elder flowers and leaves; the leaves of the wild cherry-tree, white water-lilies, tobacco, and fage; as well as from many other plants. According to our author, the plaineft proof of its exifting almoft univerfally in the vegetable kingdom, is, that the foot of our chimneys affords a volatile alkali by diftillation, either with or without quicklime.

Volatile alkali, when pure, appears of a fnowy whitenefs; has a very pungent fmell, without any difagreeable empyreuma; is very eafily evaporable, without leaving any refiduum; effervefces with acids much more ftrongly than fixed alkali; and forms with them neutral compounds called *ammoniacal falts*, which we have already defcribed, and which are different according to the nature of the acid made ufe of; for all volatile alkalies, when perfectly purified, appear to be the very fame, without the fmalleft difference.

Like fixed alkalies, thefe falts contain a great quantity of fixed air, on which their folidity depends; and which may be fo increafed as perfectly to neutralize, and deprive them of their peculiar tafte and fmell. When neutralized by fixed air, they have a very agreeable pungent tafte, fomewhat refembling that of weak fermenting liquors. When totally deprived of fixed air, by means of lime, they cannot be reduced to a folid form; but are diffipated in an invifible and exceedingly pungent vapour, called by Dr Prieftley *alkaline air*. When volatile alkaline falt is diffolved in water, the folution is called *volatile alkaline fpirit*.

Diftillation and Purification of *Volatile Alkalies*.

1031 Diftilling veffel, and method of performing the operation.

The materials moft commonly ufed for preparing volatile alkalies are the folid parts of animals, as bones, horns, *&c.* Thefe are to be put into an iron pot of the fhape recommended for folution; to this muft be fitted a flat head, having a hole in the middle about two inches diameter. From this a tube of plate-iron muft iffue, which is to be bent in fuch a manner that the extremity of it may enter an oily jar, through an hole made in its upper part, and dip about half an inch under fome water placed in the lower part. The mouth of the jar is to be fitted with a cover, luted on very exactly; and having a fmall hole, which may be occafionally ftopped with a wooden peg. The junctures are to be all luted as clofe as poffible, with a mixture of clay, fand, and fome oil; and thofe which are not expofed to a burning heat, may be further fecured by quicklime and the white of an egg, or by means of glue. A fire being now kindled, the air contained in the diftilling veffel is firft expelled, which is known by the bubbling of the water; and to this vent muft be given by pulling out the wooden peg. A confiderable quantity of phlegm will then come over, along with fome volatile alkali, a great quantity of fixable air, and fome oil. The alkali will unite with the water, and likewife fome part of the fixed air, the oil fwimming above. A great many incoercible vapours, however, will come over, to which vent muft be given from time to time, by pulling out the peg. The diftillation is to be continued till all is come over; which may be known by the ceffation, or very flow bubbling of the water. The iron pipe muft then be feparated from the cover of the diftilling veffel, left the liquid in the jar fhould return into it, on the air being condenfed by its cooling. In the jar will be a volatile fpirit, more or lefs ftrong according as there was lefs or more water put in, with an exceedingly fetid black oil floating upon it.

1032 Rectification.

The rectification of the volatile alkali is moft commodioufly performed at once by combining it with an acid; and, as fpirit of falt has the leaft affinity with inflammable matter, it is to be chofen for this purpofe, in preference to the vitriolic or nitrous. As the fpirit is exceffively oily, though already much weakened by the admixture of the water in the jar, if a very large quantity was not originally put in, an equal quantity of water may ftill be added, on drawing off the fpirit. That as little may be loft as poffible, the fpirit fhould be received in a ftone bottle; and the marine acid, likewife in a diftilled ftate, added by little and little, till the effervefcence ceafes. The liquor, which is now an impure folution of fal ammoniac, is to be left for fome time, that the oil may feparate itfelf; it is then to be filtered, evaporated, and cryftallized in a leaden veffel. If the cryftals are not fufficiently pure at the firft, they will eafily become fo on a fecond diffolution.

1033 Volatile fal ammoniac.

From fal ammoniac thus obtained pure, the volatile alkali may be extricated by diftillation with chalk, alkaline falts, or quicklime. Alkaline falts act more brifkly than chalk, and give a much ftronger volatile alkali. The ftrength of this, however, we know may be altered at pleafure, by adding to, or depriving it of, its natural quantity of fixed air. Hence, perhaps, the beft method would be, to prepare volatile alkalies altogether in a fluid ftate, by means of quicklime; and then add fixed air to them, by means of an apparatus fimilar to that directed by Dr Prieftley for impregnating water with fixed air. To prevent lime from adhering to the diftilling veffels in which it is put, the tranflator of Wiegleb's chemiftry recommends the putting in three or four ounces of common falt along with the other ingredients.

Volatile alkalies COMBINED,

1034 Cuprum ammoniacale.

I. *With Metals*. There are only three metals, *viz.* copper, iron, and lead, upon which, while in their metallic form, volatile alkalies are capable of acting. Copper-filings are diffolved by volatile alkali, efpecially in its cauftic ftate, into a liquor of a moft admirable blue colour. It is remarkable, that this colour depends entirely upon the air having accefs to the folution: for if the bottle containing it is clofe ftopt, the liquor becomes colourlefs; but, however, refumes its blue colour on being expofed to the air. On evaporation, a blue faline mafs is obtained, which, mixed with fats, or other inflammable matters, tinges their flame green, leaving a red calx of copper, foluble again in volatile fpirits as at firft. This faline fubftance ſtance has beed received into the laſt edition of the Edinburgh Diſpenſatory, under the name of *cuprum ammoniacale*, as an antiepileptic.

The blue mixture of ſolution of copper in aquafortis
1035 Copper, fulminating. with volatile ſpirits, yields ſapphire-coloured cryſtals, which diſſolve in ſpirit of wine, and impart their colour to it. If, inſtead of cryſtallization, the liquor be totally evaporated, the remaining dry matter explodes, in a moderate heat, like aurum fulminans. This is given as a fact by Dr Lewis; but hath not ſucceeded upon trial by Dr Black. Various phenomena, ſays Mr Wiegleb, occur in the diſſolution of copper by the volatile alkali.—On ſaturating dilute ſpirit of ſal ammoniac with copper-filings, cryſtals are formed of a dark-blue colour, but which, by expoſure to the air, fall to pieces and become green. Vinous ſpirit of ſal ammoniac impregnated with copper, loſes in an inſtant its blue colour, on the affuſion of an equal quantity of ſaturated ſolution of fixed alkaline ſalt. The copper is then taken up by the fixed alkaline ſolution, which of conſequence acquires a blue colour, while the ſpirit of wine, deprived of the metal, floats clear on the top. When filings of copper are put into a bottle, and that bottle quite filled with cauſtic volatile alkali, and is immediately ſtopped up, no ſolution takes place: but when the bottle is left open, only for a ſhort time, or an empty ſpace is left in it, a colourleſs ſolution is obtained, which in the air obtains a blue colour; but which may be deprived of this colour as often as we pleaſe, by ſhutting it up exactly from the air, and letting it ſtand, in this ſituation, on freſh filings of copper.—From theſe phenomena Mr Wiegleb concludes, that copper does not diſſolve in volatile alkali until it has loſt part of its phlogiſton, to which the air, by the attraction it exerts upon it, contributes its ſhare. If this has taken place only in a ſmall proportion, and the farther acceſs of air be prevented, the remainder will be diſſolved without any colour; which, however, appears in the inſtant that, by a freſh acceſſion of air, the phlogiſton ſtill remaining finds means to eſcape. The diſſolved copper is always precipitated when the ſolution meets with phlogiſticated copper. The colourleſs ſolution is precipitated by zinc and vitriolic acid, but not by iron. It taſtes rather ſweet, and does not ſmell very ſtrong of volatile alkali; while, on the contrary, the blue ſolution has a pungent ſmell, and is precipitated by diſtilled water.

On the other two metals the action of volatile alkali is by no means ſo evident; it diſſolves iron very ſlowly into a liquor, the nature of which is not known; and lead is corroded by it into a mucilaginous ſubſtance.

II. *With Inflammable Subſtances.* With expreſſed oils, the cauſtic volatile alkali unites into a ſoft unctuous maſs, of a very white colour, imperfectly ſoluble in water, and which is ſoon decompoſed ſpon-
1036 taneouſly. Compoſitions of this kind are frequently
Sal volatile oleoſum. uſed for removing pains, and ſometimes with ſucceſs. With eſſential oils, volatile alkalies may be united, either in their dry or liquid form, by means of diſtillation. The produce is called *ſal volatile oleoſum;* it is much more frequently uſed in a liquid than in a dry form. The general method of preparation is by diſtilling volatile alkali along with eſſential oils and ſpirit of wine, or the aromatic ſubſtance from whence the eſſential oils are drawn. Theſe compoſitions are variable at pleaſure; but certain forms are laid down in the diſpenſatories, with which it is expected that all the chemiſts ſhould comply in the preparation of theſe medicines.

1037 Spiritus volatilis ſuccinatus.
III. *Eau de Luce.* This is the name given to an exceedingly volatile ſpirit, which ſome years ago was pretty much in vogue; and indeed ſeems very well calculated to anſwer all the purpoſes for which volatile alkalies can be uſed. It was of a thick white colour, and ſmelled ſomewhat of oil of amber. A receipt appeared in Lewis's Diſpenſatory for the preparation of this fluid, under the name of *ſpiritus volatilis ſuccinatus.* The method there directed, however, did not ſucceed; becauſe, though the alkaline ſpirit is capable of keeping a ſmall quantity of oil of amber ſuſpended, the colour is greatly more dilute than that of genuine eau de luce. In the Chemical Dictionary we have the following receipt: "Take four ounces of rectified ſpirit of wine, and in it diſſolve 10 or 12 grains of white ſoap; filter this ſolution; then diſſolve in it a drachm of rectified oil of amber, and filter again. Mix as much of this ſolution with the ſtrongeſt volatile ſpirit of ſal ammoniac, as will be ſufficient, when thoroughly ſhaken to give it a beautiful milky appearance. If upon its ſurface be formed a cream, ſome more of the oily ſpirit muſt be added."

This receipt likewiſe ſeems inſufficient. For the oil of amber does not diſſolve in ſpirit of wine: neither is it probable that the ſmall quantity of ſoap made uſe of could be of any ſervice; for the ſoap would diſſolve perfectly in the alkaline ſpirit, without ſuffering any decompoſition. The only method which we have found to anſwer is the following. Take an ounce, or any quantity at pleaſure, of balſamum Canadenſe; place it in a ſmall china baſon, in a pan of boiling water, and keep it there till a drop of it taken out appears of a reſinous conſiſtence when cold. Extract a tincture from this reſin with good ſpirit of wine; and having impregnated your volatile ſpirit with oil of amber, lavender or any other eſſential oil, drop in as much of the ſpiritous tincture as will give it the deſired colour. If the volatile ſpirit is very ſtrong, the eau de luce will be thick and white, like the cream of new milk; nor is it ſubject to turn brown with keeping 1038

IV. *With Volatile Tincture of Sulphur.* This is a combination of the cauſtic volatile alkali, or ſpirit of ſal ammoniac, with ſulphur. It is uſually directed to be made by grinding lime with the ſulphur and afterwards with the ſal ammoniac, and diſtilling the whole in a retort, but the produce is by this method very ſmall, and even the ſucceſs uncertain. A preferable method ſeems to be, to impregnate the ſtrongeſt cauſtic volatile ſpirit with the vapour which ariſes in the decompoſitions of hepar ſulphuris by means of an acid, in the ſame manner as directed for impregnating water with fixed air. 1039

Volatile alkali combined with ſulphur.

This preparation has a moſt nauſeous fetid ſmell, which ſpreads to a conſiderable diſtance; and the effluvia will blacken ſilver or copper, if barely placed in the neighbourhood of the unſtopped bottle. This property renders it capable of forming a curious kind of ſympathetic ink; for if paper is wrote upon with a ſolution of ſaccharum ſaturni, the writing, which diſappears when dry, will appear legible and of a browniſh

Sympathetic ink.

Phenomena from mixtures of acid, &c. ſalts.

browniſh black, by barely holding it near the mouth of the bottle containing volatile tincture of ſulphur. The vapours of this tincture are ſo exceedingly penetrating, that it is ſaid they will even penetrate through a wall, ſo as to make a writing with ſaccharum ſaturni appear legible on the other ſide; but this is much to be doubted. It is even ſaid that it cannot penetrate through the ſubſtance of paper, but only inſinuates itſelf betwixt the leaves; and hence if the edges of the leaves are glued together no black colour will appear.

§ 20. *Of the* PHENOMENA *reſulting from different mixtures of the Acid, Neutral, and Alkaline* SALTS, *already treated of.*

1040 Of mixing the acid ſpirits with one another.

1. IF concentrated oil of vitriol is mixed with ſtrong ſpirit of nitre, or ſpirit of ſalt, the weaker acid will become exceedingly volatile, and emit very elaſtic fumes; ſo that if a mixture of this kind is put into a cloſe ſtopt bottle, it will almoſt certainly burſt it. The ſame effect follows upon mixing ſpirit of ſalt and ſpirit of nitre together. In this caſe, both acids become ſurpriſingly volatile; and much of the liquor will be diſſipated in fumes, if the mixture is ſuffered to ſtand for any conſiderable time. Such mixtures ought therefore to be made only at the time they are to be uſed.

1041 Diſſolving vitriolic ſalts in nitrous or marine acids.

2. If vitriolated tartar is diſſolved in an equal quantity of ſtrong ſpirit of nitre, by heating them together in a matraſs, the ſtronger vitriolic acid will be diſplaced by the weaker nitrous one, and the liquor, on cooling, will ſhoot into cryſtals of nitre. The ſame thing happens alſo upon diſſolving vitriolated tartar, or Glauber's ſalt, in ſpirit of ſalt. This obſervation we owe to Monſ. Beaumé, and the reaſon of it has been already explained. See n° 285.

1042 Decompoſition of vitriolic ſalts by ſolutions of earth, &c. in nitrous or marine acids.

3. If vitriolated tartar, or Glauber's ſalt, is diſſolved in water, and this ſolution mixed with another conſiſting of calcareous earth, ſilver, mercury, lead, or tin, diſſolved in the nitrous or marine acids, the vitriolic acid will leave the fixed alkali with which it was combined, and, uniting with the calcareous earth or metal, fall with it to the bottom of the veſſel. This decompoſition takes place only when the vitriolic acid meets with ſuch bodies as it cannot eaſily diſſolve into a liquid, ſuch as thoſe we have juſt now mentioned; for though vitriolated tartar is mixed with a ſolution of iron, copper, &c. in the nitrous or marine acids, no decompoſition takes place. The caſe is not altered, whatever acid is made uſe of; for the marine acid will effectually ſeparate ſilver, mercury, or lead, from the vitriolic or nitrous acids.

1043 By lime-water.

4. According to Dr Lewis, if a ſolution of vitriolated tartar is dropt into lime-water, the acid will unite with the lime, and precipitate with it in an indiſſoluble ſelenite, the alkali remaining in the water in a pure and cauſtic ſtate.

1044 Of green vitriol by ſaccharum ſaturni.

5. If green vitriol is mixed with any ſolution containing ſubſtances which cannot be diſſolved into a liquid by the vitriolic acid, the vitriol will be immediately decompoſed, and the liquor will become a ſolution of iron only. Thus, if green vitriol is mixed with a ſolution of ſaccharum ſaturni, the vitriolic acid immediately quits the iron for the lead, and falls to the bottom with the latter, leaving the vegetable acid of the ſaccharum ſaturni to combine with the iron.

1045 Of ſolution of tin by ſaccharum ſaturni.

6. If ſolution of tin in aqua-regia is mixed with ſolution of ſaccharum ſaturni, the marine acid quits the tin for the lead contained in the ſaccharum; at the ſame time, the acetous acid, which was combined with the lead, is unable to diſſolve the tin which was before kept ſuſpend by the marine acid. Hence, both the ſaccharum ſaturni, and ſolution of tin, are very effectually decompoſed, and the mixture becomes entirely uſeleſs. Dyers and callico-printers ought to attend to this, who are very apt to mix theſe two ſolutions together; and no doubt many of the faults of colours dyed or printed in particular places, ariſe from injudicious mixtures of a ſimilar kind. See DYEING.

1046 Of calcareous ſolutions by mild volatile alkali.

7. If mild volatile alkali, that is, ſuch as remains in a concrete form, by being united with a large quantity of fixed air, is poured into a ſolution of chalk in the nitrous or marine acids, the earth will be precipitated, and a true ſal ammoniac formed. If the whole is evaporated to dryneſs, and a conſiderable heat applied, the acid will again part with the alkali, and combine with the chalk. Thus, in the purification of volatile alkalies by means of ſpirit of ſalt, the ſame quantity of acid may be made to ſerve a number of times. This will not hold in volatile ſpirits prepared with quicklime.

1047 Sal alembroth.

8. If equal parts of ſal ammoniac and corroſive ſublimate mercury are mixed together and ſublimed, they unite in ſuch a manner as never to be ſeparable from one another without decompoſition. The compound is called *ſal alembroth;* which is ſaid to be a very powerful ſolvent of metallic ſubſtances, gold itſelf not excepted. Its powers in this, or any other reſpect, are at preſent but little known. By repeated ſublimations, it is ſaid this ſalt becomes entirely fluid, and refuſes to ariſe in the ſtrongeſt heat.

1048 Solution of ſalts promoted by vitriolic acid.

9. If vitriolic acid is poured upon any ſalt difficult of ſolution in water, it becomes then very eaſily ſoluble. By this means, vitriolated tartar, or cream of tartar, may be diſſolved in a very ſmall quantity of water.

SECT. II. *Earths.*

THE general diviſions and characters of theſe ſubſtances we have already given; and moſt of their combinations with ſaline ſubſtances have been mentioned, excepting only thoſe of the terra ponderoſa; a ſubſtance whoſe properties have been but lately inquired into, and are not yet ſufficiently inveſtigated. In this ſection, therefore we have to take notice only of their various combinations with one another, with inflammable, or metallic ſubſtances, &c. As they do not, however, act upon one another till ſubjected to a vitrifying heat, the changes then induced upon them come more properly to be treated of under the article GLASS. Upon metallic and inflammable ſubſtances (ſulphur alone excepted), they have very little effect; and therefore what relates to theſe combinations ſhall be taken notice of in the following ſections. We ſhall here confine ourſelves to ſome remarkable alterations in the nature of particular earths by combination with certain ſubſtances, and to the phoſphoric quality of others.

Terra ponderoſa and its combinations.

§ 1. *The Terra Ponderosa.*

This earth is of the true calcareous kind, and capable of being converted into a very acrid lime; but in other reſpects is very different. It is moſt commonly met

1049 Uſually found united with the vitriolic acid.

with in the veins of rocks, united with the vitriolic acid in a maſs ſomewhat reſembling gypſum, but much heavier and more opaque; and from the great weight of this ſubſtance the earth itſelf has its name, though when freed from the acid it is by no means remarkable for this property. Its properties were firſt taken notice of by the foreign chemiſts; but they have been more accurately inveſtigated by Dr Withering, who has

1050 Dr Withering's experiment.

publiſhed his obſervations in the 74th volume of the Philoſophical Tranſactions. His experiments were not made on the gypſeous ſubſtance abovementioned; but on a combination of the earth with fixed air, which is much more uncommon, and like the other poſſeſſes a very conſiderable degree of ſpecific gravity. Both theſe combinations have the general name of *ſpathum ponderoſum*, or *ponderous ſpar*; the former being alſo called *baroſelenite*, &c.

1051 Combination of terra ponderoſa with aërial acid deſcribed.

The ſpar uſed by Dr Withering was got out of a lead mine at Alſton moor in Cumberland. Its appearance was not unlike that of a lump of alum; but on cloſer inſpection it appeared to be compoſed of ſlender ſpiculæ in cloſe contact, more or leſs diverging, and ſo ſoft that it might be cut by a knife; its ſpecific gravity from 4.300 to 4.338. It effervesced with acids, and

1052 Effects of fire upon it.

melted, though not very readily, under the blow-pipe. In a common fire it loſt its tranſparency; and on being urged with a ſtronger heat in a melting furnace, it adhered to the crucible, and ſhowed ſigns of fuſion; but did not appear to have loſt any of its fixed air, either by diminution in weight, becoming cauſtic, or loſing its power of effervesſcing with acids.

1053 Treated with marine acid.

Five hundred grains of this ſpar, by ſolution in muriatic acid, loſt 104 grains in weight, and left an inſoluble reſiduum of three grains. In another experiment, 100 grains of ſpar loſt 21; and there remained only 0.6 of a grain of inſoluble matter.

On diſſolving another hundred grains in dilute muriatic acid, 25 ounce-meaſures of air were obtained, which by proper trials appeared to be pure aërial acid; and, on precipitating the ſolution with mineral alki, 100 grains of earth were again obtained; but on diſſolving the precipitate in freſh muriatic acid, only 20 ounce-meaſures of air were produced.

1054 Precipitated by mild and cauſtic fixed alkalies.

Mild vegetable alkali precipitated a ſaturated ſolution of this ſpar in marine acid, with the eſcape of a quantity of fixed air; and the ſame effect took place on the addition of foſſil alkali; but with cauſtic alkalies there was no appearance of effervescence, though a precipitate likewiſe fell.

Fifty parts of ſpar, diſſolved in marine acid, loſt $10\frac{1}{2}$; and with cauſtic vegetable alkali, a precipitate weighing $45\frac{1}{2}$ was obtained. Phlogiſticated alkali precipitated the whole of the earth, as appeared by the addition of mild fixed alkali afterwards, which occaſioned no farther precipitation.

1055 Convertible into lime capable of decompoſing vitriolic ſalts.

Part of the precipitate thrown down by the mild alkali was expoſed to a ſtrong heat in a crucible, and then put into water. The liquid was inſtantly converted into a very acrid lime-water, which had the following remarkable properties: The ſmalleſt portion of vitriolic acid, added to this water, occaſioned an immediate and copious precipitation, which appeared even after the liquid was diluted with 200 times its bulk of pure water. 2. A ſingle drop let fall into a ſolution of Glauber's ſalt, vitriolated tartar, alum, vitriolic ammoniac, Epſom ſalt, or ſelenite, occaſioned an immediate and copious precipitate in all of them: the reaſon of which was the ſuperior attraction of the ponderous earth for the acid of theſe ſalts, which forming with it an indiſſoluble concrete, inſtantly fell to the bottom.

Terra ponderoſa and its combinations.

1056 Inſoluble precipitate thrown down by cauſtic alkali.

The precipitate thrown down by the cauſtic vegetable alkali was put into water, but exhibited no ſuch appearances as the other: even the mixture was boiled; nor had it any acrimonious taſte. On adding the three mineral acids to ſeparate portions of the precipitate itſelf, neither effervescence, nor any ſign of ſolution, appeared. After ſtanding an hour, water was added, and the acids were ſuffered to remain another hour on the powder; but on decanting them afterwards, and adding foſſile alkali to the point of ſaturation, no precipitate appeared.

The precipitate thrown down by the phlogiſticated alkali, mixed with nitre and borax, and melted with a blow-pipe on charcoal, formed a black glaſs; on flint-glaſs, a white one; and on a tobacco-pipe, a yellowiſh white one. Another portion, melted with ſoap and borax in a crucible, formed a black glaſs.

The ſmall quantity of inſoluble reſiduum formerly mentioned, appeared to be the combination of ponderous earth with vitriolic acid, called *heavy* gypſum, marmor metallicum, baroſelenite, *&c.*

1057 Analyſis and properties of aërated ponderous ſpar.

From theſe experiments the Doctor concludes, that 100 parts of this ſpar contain 78.6 of pure ponderous earth, $\frac{6}{10}$ of a grain of marmor metallicum, and 20.8 grains of fixed air. 2. The quantity of mild alkali neceſſary to ſaturate any given portion of acid, contains a greater quantity of fixed air than can be abſorbed by that quantity of terra ponderoſa which the acid is able to diſſolve. 3. The terra ponderoſa, when precipitated by means of a mild alkali, readily burns to lime; and this lime-water proves a very nice teſt of the preſence of vitriolic acid. 4. In its native ſtate the terra ponderoſa will not burn to lime; when urged with a ſtrong fire, it melts and unites with the crucible, without becoming cauſtic; nor can it be made to part with its fixed air by any addition of phlogiſton. He conjectures, therefore, that as cauſtic lime cannot unite to fixed air without moiſture, and as this ſpar ſeems to contain no water in its compoſition, it is the want of water which prevents the fixed air aſſuming its elaſtic aerial ſtate. "This ſuppoſition (ſays he) becomes ſtill more probable, if we obſerve, that when the ſolution of the ſpar in an acid is precipitated by a mild alkali, ſome water enters into the compoſition of the precipitate; for it has the ſame weight as before it was diſſolved, and yet produces only 20 ounce-meaſures of fixed air, while the native ſpar contains 25 of the ſame meaſures: ſo that there is an addition of weight equal to five ounce-meaſures of air, or three one-half grains, to be accounted for; and this can only ariſe from the water. 5. The precipitate formed by the cauſtic alkali, taking ſome of the latter down with it, forms a ſubſtance neither ſoluble in acids nor water. This inſoluble compound is alſo formed by adding the lime-water already

Terra ponderoſa and its combinations.

ready mentioned, to a ſolution of cauſtic vegetable, or foſſile fixed alkali, but not with volatile alkali. 6. Fixed vegetable as well as mineral alkali, and even volatile alkalies, whether mild or cauſtic, are capable of ſeparating terra ponderoſa from any other acid excepting the vitriolic; but from it neither mild nor cauſtic alkalies are capable of ſeparating this earth,

1058 Terra ponderoſa a teſt of the preſence of vitriolic acid.

excepting the vegetable fixed alkali, which will partly do it by an intenſe heat in the dry way. 7. This earth affords an excellent method of purifying the nitrous and marine acids from any portion of the vitriolic; for the attraction between terra ponderoſa and this acid is ſo ſtrong, that the leaſt portion of the latter will be inſtantly detected by the lime-water above

1059 White matter contained in vitriolic acid found to be gypſum.

mentioned. The vitriolic acid, Dr Withering obſerves, is commonly adulterated with a white powder, which diſcovers itſelf by turning the liquor milky when the acid is diluted with water; and this powder he finds to be gypſum, from the following properties:

1. By repeated boiling in water, ſix grains and a half were reduced to two. 2. By gentle evaporation this ſolution afforded five grains of cryſtals as hard and taſteleſs as ſelenite. 3. A precipitate was formed by mild foſſile alka on adding it to a ſolution of theſe cryſtals in water. 4. On expoſing this powder to a pretty ſtrong heat, and then putting it into water, the latter became acrid, and acquired the taſte of lime-water. 5. The inſoluble part ſuffered no change by boiling in nitrous acid: one half of it mixed with borax, and expoſed to the blow-pipe upon charcoal, melted into glaſs; the other half, mixed with borax, and expoſed to the blow-pipe upon charcoal, did the ſame; whence it appears, ſays our author, that the greateſt part of this ſubſtance was calx vitriolate or ſelenite; the remainder a vitriſiable earth. He had before found, that the heavy gypſum, or marmor metallicum, would diſſolve in concentrated vitriolic acid, but always ſeparated upon the addition of water; and from his experiments it now appears that ſelenite does the ſame.

1060 Experiments on the marmor metallicum.

Dr Withering next proceeds to give a ſet of experiments on the heavy gypſum, marmor metallicum of Cronſtadt, or the Baroſelenite of others, already mentioned. The ſpecimens he obtained were from Kilpatrick hills near Glaſgow, and a ſort with ſmaller cryſtals found among the iron ore about Ketley in Shropſhire, and in the lead-mines at Alſton-Moor. He deſcribes it as white, nearly tranſparent, but without the property of double refraction; compoſed of laminæ of rhomboidal cryſtals, and decrepitating in the fire; the ſpecific gravity from 4.402 to 4.440.

1061 Deſcription of a kind found near Edinburgh.

The ſpecimens we have ſeen differ conſiderably from this deſcription, being compoſed, to appearance, of thin laminæ; which all together form a very opaque white maſs, which has not the leaſt tranſparency unleſs ſplit exceſſively thin. They are found about three miles to the ſouthweſt of Edinburgh, near Pentland hills, and likewiſe betwixt Edinburgh and Leith. In the former place they lie in ſmall veins of a rock conſiſting of a kind of iron ſtone, and ſo cloſely adhering to it, that it would ſeem either that the ſtone is converted into the ſpathum ponderoſum, or the latter into the ſtone. It is therefore often intermixed with the rock ſo intimately, that it is impoſſible to ſeparate them perfectly from each other.

Terra ponderoſa and its combinations.

Dr Withering having expoſed 100 grains of the marmor metallicum to a red heat for an hour, in a black crucible, found that it had loſt five grains of its weight; but as a ſulphureous ſmell was perceptible, he ſuſpected that a decompoſition had taken place, and therefore expoſed another portion to a ſimilar heat in a tobacco-pipe, which had no ſmell of ſulphur, nor was it diminiſhed in weight. It melted with borax into a white opaque glaſs, but was barely fuſible by itſelf under the blow pipe. It did not ſeem to diſſolve in water, nor in any of the acids, except the vitriolic, when by long boiling it had become very concentrated and almoſt red hot. It then appeared perfectly diſſolved; but ſeparated again unchanged on the addition of water. On expoſing the vitriolic ſolution to the atmoſphere for ſome days, beautiful radiated cryſtals were formed in it.

1062 Effects of heat upon it.

1063 May be diſſolved in very concentrated vitriolic acid.

1064 Precipitated from it unchanged by vegetable fixed alkali.

On adding a ſolution of mild vegetable alkali to this vitriolic ſolution, a precipitate appeared; but it conſiſted of marmor metallicum unchanged. An ounce of it in fine powder was then fuſed with two of ſalt of tartar until it ran thin, when ſix drachms of a reſiduum inſoluble in water were left. On the addition of nitrous acid, only 52 grains were left, which appeared to be marmor metallicum unchanged. On ſaturating the alkaline ſolution with diſtilled vinegar, and waſhing the precipitate, the liquor was found to contain terra foliata tartar, formed by the union of the acetous acid with part of the alkali; and of vitriolated tartar, formed by that of the alkali with the native acid of the marmor metallicum.

1065 May be decompoſed in the dry way by ſalt of tartar.

1066 Nitrous ſolution ſhoots into fine cryſtals.

The ſalt formed by the nitrous acid ſhot readily into beautiful permanent cryſtals of a rough bitteriſh taſte. Some of the ſalt deflagrated with nitre and charcoal, left by waſhing the terra ponderoſa very white, capable of being burnt into lime, and again forming an inſoluble compound with vitriolic acid. An hundred grains of aerated terra ponderoſa, diſſolved in marine acid, and precipitated by the vitriolic, were augmented 17 grains in weight. Hence it appears,

1067 Analyſis and properties of the marmor metallicum.

1. That the marmor metallicum is compoſed of vitriolic acid and terra ponderoſa. 2. That this compound has very little ſolubility in water. 3. That it can only be diſſolved in highly concentrated oil of vitriol, from which it ſeparates unchanged on the addition of water. 4. That it cannot be decompoſed in the moiſt way, by mild fixed alkali, though it may be ſo in the dry. 5. That it may be decompoſed by the union of inflammable matter to its acid, by which ſulphur is formed, though the acid cannot be diſſipated by mere heat. 6. An hundred parts of this ſubſtance contain 32.8 of pure vitriolic acid, and 57.2 of terra ponderoſa. The marmor metallicum, our author remarks, may poſſibly be uſeful in ſome caſes where a powerful flux is wanted; for having mixed ſome of it with the black flux, and given the mixture a ſtrong heat in a crucible, it ran entirely through the pores of the veſſel.

1068 Cauk, a ſubſtance of this kind, found in Derbyſhire in England.

Dr Withering deſcribes two other kinds of this ſubſtance, known by the name of *cauk*, and found in the mines of Derbyſhire, and other places. Theſe differ from the other only in containing a ſmall proportion of iron. On the whole, he concludes, that "the terra ponderoſa ſeems to lay claim to a middle place betwixt the earths and metallic calces. Like the for-

U mer-

Transmutation of flints into an earth soluble in acids. mer it cannot be reduced to a metallic form, though like the latter it may be precipitated by phlogisticated alkali. In many of its properties it much resembles the calx of lead, and in others the common calcareous earth. Its most remarkable properties are its decomposing the vitriolic neutral salts, and forming, with the nitrous and marine acids, crystals which do not deliquesce.

§ 2. *Transmutation of* Flints *into an* Earth *soluble in Acids.*

1069 Solution of flint. This is effected by mixing powdered flints with alkaline salt, and melting the mixture by a strong fire. The melted mass deliquates in the air, like alkaline salts; and if the flint is then precipitated, it becomes soluble in acids, which it entirely resisted before.

In this process the alkali, by its union with the flint, is deprived of its fixed air, and becomes caustic. To this causticity its solvent power is owing; and therefore the flint may be precipitated from the alkali, not only by acids, but by any substance capable of furnishing fixed air; such as magnesia alba or volatile alkali. The precipitate in both cases proves the same; but the nature of it hath not hitherto been determined. Some have conjectured that the vitriolic acid existed in the flint; in which case, the alkali made use of in this process ought to be partly converted into vitriolated tartar.

1070 Solubility of this earth denied by Mr Bergman. The above process is delivered on the authority of former chemists; but Mr Bergman, who has published a dissertation on this subject, asserts that it cannot be dissolved except by the fluor acid. The vitriolic, nitrous, or marine acids, have no effect upon it, even when newly precipitated from the liquor of flints washed and still wet, and though a thousand parts of acid be added to one of the earth, and boiled upon it for an hour: but when three parts of alkaline salt are melted in a crucible with one of quartz, the salt dissolves at the same time about seven hundredth parts of its own weight of the clay which composes the crucible; and the solubility of this has given occasion to the mistake abovementioned. If the fusion be performed in an iron vessel, no soluble part will be obtained, excepting the very small portion of clay which the quartz contains; and when this is once exhausted by an acid, no more can be procured by any number of fusions with alkali.

1071 Reason of the mistake of former chemists.

1072 Crystals of flint artificially formed by Mr Bergman. The fluor acid, he observes, is never obtained entirely free from siliceous earth, and consequently its power as a menstruum must be weakened in proportion to the quantity it contains. In order to observe its solvent power, however, our author, in the year 1772, put some quartz, very finely powdered, into a bottle containing ⅓ of a kanne of fluor acid. The bottle was then slightly corked, and set by in the corner of a room. Two years afterwards it was examined; and on pouring out the liquor there were found concreted at the bottom of the vessel, besides innumerable small prismatic spiculae, 13 crystals of the size of small peas, but mostly of an irregular form. Some of these resembled cubes, whose angles were all truncated, such as are often found in the cavities of flints. These were perfect siliceous crystals, and very hard, but not comparable with quartz, though they agreed with it in essential properties. "Possibly (says he) the length of a century may be necessary for them to acquire, by exsiccation, a sufficient degree of hardness. The bottom itself, as far as the liquor had reached, was found covered with a very thin siliceous pellicle, which was scarcely visible, but separated on breaking the bottle. It was extremely pellucid, flexible, and showed prismatic colours. These phenomena show that much siliceous matter is dissolved and suspended." (in the fluor acid). "Whether any of the quartz was taken up in this experiment is uncertain; but it appears probable that little or none was dissolved; since, by the help of heat during the distillation, the acid had previously taken up so much siliceous earth, that upon slow evaporation it was unable to retain it. Hence appears the origin of the crystals and the pellicle; and hence appears the cause which impedes the action of fluor acid upon flint; namely, that the acid obtained in the ordinary way is already saturated with it.

Transmutation of flints into an earth soluble in acids.

1073 Why the fluor acid will not dissolve flint directly.

1074 Siliceous earth most completely precipitated by volatile alkali. The volatile alkali precipitates siliceous earth most completely from fluor acid: and thus we find, that one part of it is contained in 600 of the acid, diluted to such a degree, that its specific gravity is only 1.064. This precipitate has all the properties of pure flint; but that precipitated either by vegetable or mineral fixed alkali does not afford a pure siliceous earth, but a peculiar kind of triple salt, formed of the earth, fluor acid, and fixed alkali, which dissolves, though with difficulty, in warm water, especially the earth procured by vegetable alkali, but is easily decomposed by lime-water and lets fall the mineral fluor regenerated.

1075 A triple salt formed by precipition with fixed alkali.

1076 Siliceous earth dissolved by boiling in solution of alkali. Fixed alkaline salts attack this earth by boiling, but not unless it be reduced to very fine powder, and newly precipitated from the liquor. Oil of tartar per deliquium takes up about one-sixth of its weight, and the liquor becomes gelatinous on cooling, though at first diluted with 16 times its weight of water. This solution is effected only by the caustic part; for when fully saturated with fixed air, it cannot enter into any union with it. Volatile alkali, even though caustic, has no effect.

1077 Has a remarkable attraction for it in the dry way. The attraction betwixt siliceous earth and fixed alkali is much more remarkable in the dry way; for thus it melts with one half its weight of alkali into an hard, firm, and transparent glass, the aerial acid and water going off in a violent effervescence. In proportion as the alkali is increased, the glass becomes more soft and lax, until at last it dissolves totally in water, as has been already mentioned. The siliceous matter thus precipitated is of a very rare and spongy texture, and so much swelled by water, and its bulk when wet is at least twelve times greater than when dry; nor does it contract more though suffered to remain a long time in the water. Hence it is easy to reduce the liquor of flints to a jelly, by diluting it with four or eight times its weight of water, and adding a sufficient quantity of precipitate; but if an overproportion of water be used, for instance, 24 times the weight, the liquor will then remain limpid though we add as much acid as is sufficient for saturating the alkali. The reason of this Mr Bergman supposes to be, that the siliceous particles are removed to such a distance from one another, that they cannot overcome the

1078 Is very rare and spongy when precipitated.

1079 Why it cannot sometimes be precipitated by an acid without heat.

Phosphoric earths. the friction they must necessarily meet with in their passage downwards through the fluid; but if the liquor be boiled, which at once diminishes its quantity and tenacity, the siliceous matter is instantly separated.

1080 Liquor of flints decomposed by too great a quantity of water, and by fluor acid. Liquor of flints is also decomposed by too great a quantity of water; for by this the efficacy of the menstruum is weakened, and it is also partly saturated by the aerial acid contained in the water. A precipitate also falls when the fluor acid is made use of; the reason of which is the same as the precipitation by other acids: in this case, however, the alkali makes part of the precipitate, as has been already observed; and therefore the matter which falls is fusible before the blowpipe, and soluble in a sufficient quantity of water.

§ 3. *Of* Phosphoric *Earths.*

1081 Bolognian stone. These are so called from their property of shining in the dark. The most celebrated and anciently known of this kind is that called the *Bolognian stone*, from Bologna, a city in Italy, near which it is found. The discovery, according to Lemery, was accidentally made by a shoe-maker called *Vincenzo Casciarolo*, who used to make chemical experiments. This man, having been induced to think, from the great weight and lustre of these stones, that they contained silver, gathered some, and calcined them; when carrying them into a dark place, probably by accident, he observed them shining like hot coals.

Mr Margraaf describes the Bolognian stone to be an heavy, soft, friable, and crystallized substance, incapable of effervescence with acids before calcination in contact with burning fuel. These properties seem to indicate this stone to be of a selenitic or gypseous nature.

1082 How rendered luminous. When these stones are to be rendered phosphoric, such of them ought to be chosen as are the cleanest, best crystallized, most friable and heavy; which exfoliate when broken, and which contain no heterogeneous parts. They are to be made red hot in a crucible; and reduced to a very fine powder in a glass-mortar, or upon a porphyry. Being thus reduced to powder, they are to be formed into a paste with mucilage of gum tragacanth, and divided into thin cakes. These are to be dried with a heat, which at last is to be made pretty considerable. An ordinary reverberating furnace is to be filled to three quarters of its height with charcoal, and the fire is to be kindled. Upon this charcoal the flat surfaces of the cakes are to rest, and more charcoal to be placed above them, so as to fill the furnace. The furnace is then to be covered with its dome, the tube of which is to remain open; all the coal is to be consumed, and the furnace is to be left to cool; the cakes are then to be cleansed from the ashes by blowing with bellows upon them. When they have been exposed during some minutes to light, and afterwards carried to a dark place, they will seem to shine like hot coals; particularly if the person observing them has been some time in the dark, or have shut his eyes, that the pupils may be sufficiently expanded. After this calcination through the coals, if the stones be exposed to a stronger calcination, during a full half hour, under a muffle, their phosphoric quality will be rendered stronger.

From attending to the qualities of this stone, and the requisites for making this phosphorus, we are naturally led to think, that the Bolognian phosphorus is no other than a composition of sulphur and quicklime. The stone itself, in its natural state, evidently contains vitriolic acid, from its not effervescing with acids of any kind. This acid cannot be expelled from earthy substances by almost any degree of fire, unless inflammable matter is admitted to it. In this case, part of the acid becomes sulphureous, and flies off; while part is converted into sulphur, and combines with the earth. In the abovementioned process, the inflammable matter is furnished by the coals in contact with which the cakes are calcined, and by the mucilage of gum tragacanth with which the cakes are made up. A true sulphur must therefore be formed by the union of this inflammable matter with the vitriolic acid contained in the stone; and part of this sulphur must remain united to the earth left in a calcareous state, by the dissipation, or conversion into sulphur, of its acid. Phosphoric earths. 1083 Analysis of the phosphorus.

In the year 1730, a memoir was published by Mr du Fay; wherein he asserts, that all calcareous stones, whether they contain vitriolic acid or not, are capable of becoming luminous by calcination: with this difference only, that the pure calcareous stones require a stronger, or more frequently repeated, calcination to convert them into phosphorus; whereas those which contain an acid, as selenites, gypsum, spars, *&c.* become phosphoric by a slighter calcination. On the contrary, Mr Margraaf asserts, that no other stones can be rendered phosphoric but those which are saturated with an acid; that purely calcareous stones, such as marble, chalk, limestone, stalactites, *&c.* cannot be rendered luminous, till saturated with an acid previously to their calcination. 1084 All calcareous stones phosphoric, according to Mr du Fay.

We have already taken notice, that the compounds formed by uniting calcareous earths with the nitrous and marine acids become a kind of phosphori; the former of which emits light in the dark, after having been exposed to the sun through the day; and the latter becomes luminous by being struck. Signior Beccaria found, that this phosphoric quality was capable of being given to almost all substances in nature, metals perhaps excepted. He found that it was widely diffused among animals, and that even his own hand and arm possessed it in a very considerable degree. In the year 1775, a treatise on this kind of phosphori was published by B. Wilson, F. R. S. and member of the Royal Academy at Upsal. In this treatise he shows, that oyster-shells, by calcination, acquire the phosphoric quality in a very great degree, either when combined with the nitrous acid or without it. 1085 Signior Beccaria's observation. 1086 Mr Wilson's experiments.

The first experiment made by our author was the pouring some aquafortis, previously impregnated with copper, on a quantity of calcined oyster-shells, so as to form them into a kind of paste; he put this paste into a crucible, which was kept in a pretty hot fire for about 40 minutes. Having taken out the mass, and waited till it was cool, he presented it to the external light. On bringing it back suddenly into the dark, he was surprised with the appearance of a variety of colours like those of the rainbow, but much more vivid. In consequence of this appearance of the prismatic colours, Vegetable earth. colours, he repeated the experiment in various ways, combining the calcined oyster-shells with different metals and metallic solutions, with the different acids, alkaline and neutral salts, as well as with sulphur, charcoal, and other inflammable substances; and by all of these he produced phosphori, which emitted variously coloured light.

1087 Surprising phosphoric quality of oyster-shells. What is more remarkable, he found that oyster-shells possessed the phosphoric quality in a surprising degree; and for this purpose nothing more was requisite than putting them into a good sea-coal fire, and keeping them there for some time. On scaling off the internal yellowish surface of each shell, they become excellent phosphori, and exhibit the most vivid and beautiful colours. As we know that neither the vitriolic nor any other acid is contained in oyster-shells, we cannot as yet say any thing satisfactory concerning the nature of this phosphorus.

§ 4. *Of the* Vegetable *Earth.*

1088 Dr Lewis's opinion. This is produced from vegetables by burning, and, when perfectly pure, by lixiviating the ashes with water, to extract the salt; and then repeatedly calcining them, to burn out all the inflammable matter; and is perhaps the same from whatever substance it is obtained: in this state, according to Dr Lewis, it is of the same nature with magnesia. In the state, however, in which this earth is procurable by simply burning the plant, and lixiviating the ashes, it is considerably different, according to the different plants from

1089 Mr Gmelin's experiments. which it is obtained. The ashes of mugwort, small centaury, chervil, and dill, are of a brownish grey; goat's beard and lungwort afford white ashes; those of sanicle are whitish; those of Roman wormwood of a greenish grey; those of rue, agrimony, saxifrage, brown; those of tansey, of a dusky green; those of dodder, of a fine green; eyebright, southern-wood, common wormwood, and scabious, afford them grey; scurvy-grass, of a whitish grey; hyssop, yarrow, and sowbane, of a dusky grey; melilot, and oak-leaves, as also plantain, colts-foot, pine-tops, and fumitory, of a dusky brown; penny-royal, of a pale brown, with some spots of white; elder-flowers, sage, and mother of thyme, afford yellow ashes; those of strawberry-leaves are of a pale brimstone colour; those of cat-mint, of a dusky red; of prunella, brick-coloured; of honey-suckle, blue; of fern, blackish; and those of St John's wort, feverfew, origanum, and pimpernel, all of a deep black. The only use to which this kind of earth has yet been put, is that of glass-making and manure.

Sect. III. *Of Metallic Substances.*

§ 1. Gold.

Gold. This metal is reckoned of all others the most perfect and indestructible. When in its greatest purity, it has very little elasticity, is not sonorous, its colour is yellow, it is exceedingly soft and flexible, and is more ductile than any other metal whatever. (See Gold *Leaf*, and Wire-Drawing.) Of all bodies it is the most ponderous, except platina; its gravity being to that of water, according to Dr Lewis, as 19,280, or 19,290, to one. For its fusion it requires a low degree of white heat, somewhat greater than that in which silver melts. Whilst fluid, it appears of a bluish green colour; when cold, its surface looks smooth, bright, and considerably concave: it seems to expand more in the act of fusion, and to shrink more in its return to solidity, than any of the other metals; whence the greater concavity of its surface. Before fusion it expands the least of all metals, except iron. By sudden cooling it becomes, as well as other metals, brittle; which effect has been erroneously attributed to the contact of fuel during fusion.

1090 Unites readily with all the metals. Gold amalgamates very readily with mercury, and mingles in fusion with all the metals. It is remarkably disposed to unite with iron; of which it dissolves many times its own weight, in a heat not much greater than that in which gold itself melts; the mixture is of a silver colour, very brittle and hard. All the metals, except copper, debase the colour of gold; and, if their quantity is nearly equal to that of the gold, almost entirely conceal it.

1091 Said to lose its malleability remarkably with tin. The malleability of gold is impaired by all the metals, but less by copper and silver than any others. Tin has had a remarkably bad character in this respect; and it has been a received opinion among metallurgists, that the smallest quantity of this metal entirely destroys the ductility of gold; and Dr Lewis tells us, that "the most minute portion of tin or lead, and even the vapours which rise from them in the fire, though not sufficient to add to the gold any weight sensible on the tenderest balance, make it so brittle,

1092 Mr Alchorne's experiments in opposition. that it flies to pieces under the hammer." On so respectable an authority, this continued to be believed as an undoubted fact, until, in the year 1784, a paper appeared in the Philosophical Transactions by Mr Alchorne of the mint: in which it was clearly disproved by the following experiments:

1. Sixty Troy grains of pure tin were put into 12 ounces of pure gold in fusion; after which the mixture was cast into a mould of sand, producing a flat bar an inch wide, and an eight of an inch thick. The bar appeared sound and good, suffered flatting under the hammer, drawing several times between a pair of steel-rollers, and cutting into circular pieces of near an inch diameter, which bore stamping in the money-press by the usual stroke, without showing the least brittleness, or rather with much the same ductility as pure gold.

2. With 90 grains of tin the bar was scarce distinguishable from the former.

3. With 120 grains it was rather paler and harder; and on drawing between the rollers the edges were a little disposed to crack.

4. With 140 grains, the paleness, hardness, and disposition to crack, were evidently increased; nevertheless it bore every other operation, even stamping under the press, without any apparent injury.

5. With an ounce of tin the bar was lead-coloured and brittle, splitting into several pieces on the first passing between the rollers.

1093 Gold not rendered brittle by the fumes of tin. 6. A small crucible filled with standard gold 22/24 fine, was placed in a larger one, having in it an ounce of melted tin. The whole was covered with a large crucible inverted, in order to direct the fumes of the tin downward upon the gold. The metals were kept in fusion

Gold.

fusion for half an hour, during which time a full quarter of the tin was calcined; yet the gold remained altogether unchanged.

7. The mixture of gold and tin produced in exp. 1. was melted a second time in a stronger fire than at first, and kept in fusion for half an hour; during which time six grains of weight were lost, but the gold remained equally perfect as before.

1094
Nor by the addition of copper.

8. and 9. The mixtures of exp. 2. and 4. viz. 90 and 140 grains to 12 ounces of gold, were re-melted separately, and an ounce of copper added to each. On being cast as usual, they bore all the operations of manufacturing as before, though sensibly harder. The last cracked at the edges as it had done without the copper, but bore cutting rather better than in its former state.

10. and 11. A quarter of an ounce of the last mixture, being tin 140 grains, and copper an ounce, and gold 12 ounces, with as much of the bar from experiment 3. consisting of 140 grains of tin to 12 ounces of gold, were each melted by a jeweller in a common sea-coal fire, into small buttons, without any loss of weight. These buttons were afterwards forged into small bars, nealing them often with the flame of a lamp, and afterwards drawn each about twenty times through the apertures of a steel plate, into fine wire, with as much ease as coarse gold commonly passes the like operation.

12. Sixty grains of tin were added to 12 ounces of standard gold $\frac{22}{24}$ fine; and the compound passed every one of the operations already described, without showing the least alteration from the tin.

Several other trials were made with different mixtures of copper, tin, and silver, with gold, even as low as two ounces and a half of copper, with half an ounce of tin, to twelve ounces of gold; all of which bore hammering and flatting by rollers to the thinness of stiff paper, and afterwards working into watch-cases, cane-heads, &c. with great ease. They grew more hard and harsh indeed in proportion to the quantity of alloy; but not one of them had the appearance of what workmen call brittle gold. Mr Alchorne therefore is of opinion, that when brittleness has been occasioned by the addition of tin to gold, the former has been adulterated with arsenic; as he has found, that by adding 12 grains of regulus of arsenic to as many ounces of fine gold, the compound has been rendered altogether unmalleable,

1095
Malleability of gold destroyed by regulus of arsenic.

When gold is struck during a certain time by a hammer, or when violently compressed, as by the wire-drawers, it becomes more hard, elastic, and less ductile; so that it is apt to be cracked and torn. Its ductility is, however, restored by the same means used with other metals, namely, heating it red hot, and letting it cool slowly. This is called *annealing* metals; and gold seems to be more affected by this operation than any other metal. The tenacity of the parts of gold is also very surprising; for a wire of $\frac{1}{10}$ of an inch in diameter will support a weight of 500 pounds.

1096
Surprising tenacity of its parts.

1097
Not liable to rust.

Gold is unalterable by air or water. It never contracts rust like other metals. The action of the fiercest furnace-fires occasions no alteration in it. Kunckel kept gold in a glass-house furnace for a month, and Boyle kept some exposed to a great heat for a still longer time, without the loss of a single grain. It is said, however, to be dissipable in the focus of a large burning mirror.

Gold.

1098
Mr Boyle's experiments for the destructibility of gold.

Mr Boyle relates a very curious and extraordinary experiment, which he thought was sufficient to prove the total destructibility of gold. About an eighth part of a grain of powder, communicated by a stranger, was projected upon two drachms of fine gold in fusion, and the matter kept melted for a quarter of an hour. During the fusion, it looked like ordinary gold; except only once, that his assistant observed it to look exactly of the colour of opal. When cold, it was of a dirty colour, and, as it were, overcast with a thin coat, almost like half-vitrified litharge: the bottom of the crucible was overlaid with a vitrified substance, partly yellow, and partly reddish brown; with a few small globules, more like impure silver than gold. The metal was brittle, internally like brass or bell-metal; on the touchstone more like silver than gold: its specific gravity was to that of water only as $15\frac{1}{2}$ to 1. There was no absolute loss of weight. By cupellation, 60 grains of this mass yielded 53 grains of pure gold, with seven grains of a ponderous, fixed, dark-coloured substance.

1099
Solution in aqua-regia.

We have already mentioned, that in certain circumstances gold is soluble in the nitrous and marine acids separately. It is, however, always soluble by the two united, but dissolves slowly even then. The most commodious method of obtaining this solution is, by putting the gold, either in leaves, or granulated, or cut into small thin pieces, into a proper quantity of aquafortis; then adding, by degrees, some powdered sal ammoniac, till the whole of the gold is dissolved. By this means a much smaller quantity of the menstruum proves sufficient, than if the sal ammoniac was previously dissolved in the aquafortis; the conflict, which each addition of the salt raises with the acid, greatly promoting the dissolution. Aquafortis of moderate strength will, in this way, take up about one-third of its weight of gold; whereas an aqua-regis, ready prepared from the same aquafortis, will not take up above one-fifth its weight. Common salt answers better for the preparation of the aqua-regis than sal ammoniac.

1100
Properties of the solution.

This solution, like all other metallic ones, is corrosive. It gives a violet colour to the fingers, or to any animal matters. If the solution is evaporated and cooled, yellow transparent crystals will be formed: but, if the evaporation is carried too far, the acids with which the gold is combined may be driven from it by heat alone; and the gold will be left in the state of a yellow powder, called *calx of gold*.

1101
Gold precipitated from it.

Gold may be precipitated from its solution by those substances which commonly precipitate metals, such as alkaline salts and calcareous earths. It may also be precipitated in a fine purple powder, by tin or its solution.

When fixed alkalies are made use of, the precipitate weighs about one-fourth more than the gold employed. With volatile alkalies also, if they are added in no greater proportion than is sufficient to saturate the acid, the quantity of precipitate proves nearly the same: but if volatile spirit is added in an over-proportion, it redissolves part of the gold which it had before precipitated, and the liquor becomes again considerably yellow. The whole of the precipitate, how-

ever,

Gold.

ever, could not be rediſſolved, either by the mild or cauſtic alkali; nor did either of theſe ſpirits ſenſibly diſſolve or extract any tinge from precipitates of gold which had been thoroughly edulcorated with boiling water.

All the metallic bodies which diſſolve in aqua-regia, precipitate gold from it. Mercury and copper throw down the gold in its bright metalline form; the

1102 Separated from other metals by vitriol of iron.

others, in that of a calx or powder, which has no metallic aſpect. Vitriol of iron, though it precipitates gold, yet has no effect upon any other metal; hence it affords an eaſy method of ſeparating gold from all other metals. The precipitation with tin ſucceeds certainly only when the metal in ſubſtance is uſed, and the ſolution of gold largely diluted with water. It is obſervable, that though the gold is precipitated from the diluted ſolution by tin, yet, if the whole is ſuffered to ſtand till the water has in a great meaſure exhaled, the gold is taken up afreſh, and only a white calx of tin remains.

1103 Aurum fulminans.

Gold precipitated from its ſolution in aqua-regia explodes by heat with much greater violence than any

1104 Known in the 15th century.

other ſubſtance in nature. This property was known in the 15th century; but whether the ancient alchemiſts knew any thing of it or not, is a matter of un-

1105 Baſil Valentine's directions for its preparation.

certainty. Baſil Valentine firſt gave any diſtinct account of it. He directs the gold to be diſſolved in aqua-regia made with ſal ammoniac, and then precipitated by vegetable fixed alkali, to be twelve times waſhed with water, and laſtly dried in the open air, where the ſun's rays cannot reach it. He forbids it to be dried over a fire, as it explodes with a gentle heat, and flies off with inconceivable violence.

Succeeding chemiſts have performed this operation with ſome little differences; but the neceſſity of employing volatile alkali was but little regarded till the beginning of the preſent century.

1106 Uſe of volatile alkali but lately known.

The calx of gold is always ſomewhat increaſed in weight by being converted into aurum fulminans; but authors are not agreed about the quantity of augmentation. Becher makes it heavier by one-fifth part;

1107 Increaſe of the weight of gold by being changed into aurum fulminans.

Lemery by one-fourth; and Juncker by one-fourth. All agree, however, that it explodes with a violence almoſt inconceivable. Crollius relates, that 20 grains of this powder explodes with more force than half a pound of gun powder, and exerts its force downwards, though M. Teykmeyer frequently ſhowed in his lectures that it would throw a florin upwards above ſix

1108 Prodigious force with which it explodes.

ells. A great number of experiments were made before the Royal Society at London, in order to determine the comparative forces of theſe two powders. Equal parts of gunpowder and aurum fulminans were included in iron globes placed among burning coals; thoſe which contained the former burſt with great violence, but the globes containing the aurum fulminans

1109 Does not explode in cloſe veſſels.

remained perfectly ſilent. But though no exploſion takes place in cloſe veſſels, the utmoſt caution is neceſſary in managing this ſubſtance in the open air; eſpecially when it is ſubjected to friction, or to a ſlight degree of heat; for ſuch is the nature of the calx we ſpeak of, that it is not neceſſary, in order to cauſe it

1110 Heat requiſite for the exploſion.

explode, to touch it with an ignited ſubſtance, or to make it red-hot. The heat requiſite for this purpoſe is, according to Dr Lewis, intermediate between that of boiling water and the heat which makes metals of an obſcure red. With friction, however, it ſeems ſtill more dangerous; for in this caſe it explodes with what

Gold.

1111 Explodes readily by friction.

we ſhould think ſcarce ſufficient to communicate any degree of heat whatever. Orſchal relates, that this powder ground in a jaſper mortar, exploded with ſuch violence as to burſt the veſſel in a thouſand pieces;

1112 Inſtances of its miſchievous effects.

Dr Lewis gives an inſtance of a ſimilar kind in England; and Dr Birch tells us of doors and widows torn to pieces by the violence of this exploſive matter. Mr Macquer relates the following accident to which he was witneſs. "A young man, who worked in a laboratory, had put a drachm of fulminating gold into a bottle, and had neglected to wipe the inner ſurface of the neck of the bottle, to which ſome of the powder adhered. When he endeavoured to cloſe the bottle, by turning round the glaſs ſtopper, the friction occaſioned an exploſion of part of the powder. By this the young man was thrown ſome ſteps backward, his face and hands wounded by the fragments of the bottle, and his eyes put out; yet, notwithſtanding this violent exploſion, the whole drachm of fulminating gold certainly did not take fire as much of it was afterwards found ſcattered about the laboratory."

1113 Force of the exploſion is not directed entirely downwards.

It has already been mentioned, that ſome imagine the force of this exploſion to be directed downwards; but Dr Lewis is of opinion that it is equally directed every way. Certain it is, that the quantity of from 10 to 12 grains of aurum fulminans, exploded on a metalline plate, lacerates it; a ſmaller quantity forms a cavity, and a ſtill ſmaller only ſcratches the ſurface; effects which are never produced by gunpowder in ever ſo large a quantity. A weight laid upon the powder is thrown upwards in the moment of exploſion. If it be of ſilver or copper, this weight is marked with a yellowiſh ſpot, as the ſupports will alſo be, if made of either of theſe metals. A large grain, ſays Mr Bergman, brought near to the ſide of the flame of a candle, blows it out with great noiſe; and a few ounces exploding together by incautious drying, has been known to ſhatter the doors and windows of the apartment: hence it is evident, that aurum fulminans exerts its force in all directions; yet it cannot be denied, that it ſtrikes bodies with which it is in contact more violently than thoſe which are at a ſmall diſtance, though in its vicinity: thus, if a ſmall portion of it explodes in a paper box, it lacerates only the bottom, unleſs the top be preſſed down cloſe, in which caſe it perforates both the top and bottom. When carefully and gradually exploded in a glaſs phial or a paper box, it leaves a purple ſoot, in which are found many particles of ſhining gold; and if the quantity exploded be large, ſeveral grains remain totally unchanged, as it is only the lowermoſt ſtratum that is inflamed.

1114 Exploſion of moiſt aurum fulminans.

Aurum fulminans, when moiſt, does not explode at all: but as it dries, the grains go off in ſucceſſion like the decrepitation of common ſalt.—In glaſs veſſels cloſed, or with their mouths immerſed in water, it explodes, but with a very weak report. An elaſtic vapour, in the quantity of ſeven inches, from half a drachm of the powder, broke forth in the moment of exploſion, which, by our author's account, ſeems to be phlogiſticated air. In metallic veſſels ſufficiently ſtrong, the gold is ſilently reduced when they are per-

fectly

 Gold

fectly ſound; but if they have any very ſmall chinks in them, the vapour makes its way through them with a hiſſing noiſe.

1115 Cauſe of this exploſion attributed to a ſaline principle.

The cauſe of this extraordinary exploſive force of gold has been attributed chiefly to a ſaline principle, *viz.* The combination of nitrous acid with volatile alkali; and this opinion has been ſupported by an aſſertion, that the fulminating property is deſtroyed by treating the calx with vitriolic acid or with fixed alkali; the former expelling the nitrous acid, and the

1116 This opinion ſhown to be erroneous by Mr Bergman.

latter diſengaging the volatile alkali. Mr Bergman allows that fixed alkali deſtroys the fulminating property; but affirms, that it acts only by ſeparating the particles when the two are triturated together; and this might be done by many other ſubſtances as well as fixed alkali: But when the alkali, inſtead of being triturated in the dry way with the calx, was boiled in water along with it, the exploſion not only took place, but was much more violent than uſual. It muſt be obſerved, however, that heat alone deſtroys the fulminating property of this calx; and therefore, if the alkaline ſolution be made too ſtrong, the additional heat which it then becomes capable of ſuſtaining, is ſufficient to deprive the calx of its fulminating property. The caſe is the ſame with the vitriolic acid; for this has no effect upon the calx, either by digeſtion in its concentrated ſtate, or by boiling in its diluted ſtate. If it be boiled in its concentrated ſtate indeed with the fulminating calx, the heat conceived by the acid is ſufficient to deſtroy the fulminating property of the former; and in like manner, unleſs the calx be in ſome meaſure deſtroyed, or reduced to its metallic ſtate, it can never be deprived of its fulminating property.

1117 Aurum fulminans can be made without nitrous or marine acids.

It was further proved, that the fulminating property did not depend on the preſence either of nitrous or marine acids, for it can be made without them. A calx of gold, not fulminating, diſſolved in vitriolic acid, and precipitated by cauſtic volatile alkali, had acquired this property. A ſolution of the ſame calx in nitrous acid, let fall a precipitate by the addition of pure water; and this precipitate edulcorated, and digeſted with volatile alkali, fulminated as if it had been originally precipitated with that alkali. The experiment was repeated on the other non-fulminating precipitates with the ſame ſucceſs. Leſt any ſuſpicion, however, ſhould remain, that a ſmall quantity of aqua-regia might ſtill be left, which, by combining with the volatile alkali, would make a proportionable quantity of nitrum flammans, the precipitate was digeſted 24 hours in vitriolic acid, then waſhed in pure water, and immerſed in aqueous and ſpirituous ſolutions of alkali, both mild and cauſtic; but the event was the ſame. Laſtly, an inert calx of gold may always be made to fulminate by digeſting it with volatile alkali; nor can this property be communicated to it by any means without the uſe of this alkali.

1118 Fixed air not the cauſe of the exploſion.

It has been ſuppoſed by ſome very eminent chemiſts, among whom we may number Dr Black, that fixed air is the cauſe of the fulmination of gold: but it is evident that this cannot be the caſe: becauſe, 1. Gold fulminates as well when precipitated by the cauſtic volatile alkali, as by that which contains fixed air, 2. This metal does not combine, during precipitation, with fixed air. 3. Gold, when precipitated by mild fixed alkali, does not fulminate, unleſs the menſtruum contain volatile alkali.

The fulminating calx of gold may be prepared either with the compound aqua-regia of pure nitrous and marine acids; of pure nitrous acid and ſal ammoniac; or of a compound of alum, nitre, and ſea-ſalt. When 1119 Menſtruum ſine ſtrepitu.

this kind of liquor is made uſe of, the acid of the alum expels the other two, and thus forms an aqua-regia. This was formerly called *menſtruum ſine ſtrepitu*. By whatever method the gold is diſſolved, it always affords a yellow calx with alkalies, but the volatile alkali moſt readily throws down the metal. Dephlogiſticated ſpirit of ſalt very readily diſſolves gold, and produces a fulminating precipitate as well as aqua-regia.

1120 Mr Bergman's theory of the cauſe of the exploſion.

We ſhall conclude this account of aurum fulminans with an abſtract of Mr Bergman's theory of the exploſion.—He obſerves, that volatile alkali contains phlogiſton; an undoubted proof of which is given by Dr Prieſtley, by coverting alkaline into phlogiſticated air. This phlogiſton, ſays he, may be ſeparated by means of a ſuperior attraction; ſo that the volatile alkali is decompoſed, and the reſiduum diſſipated in form of an elaſtic fluid, altogether ſimilar to that which is extricated during the fulmination: the ſource then from whence the elaſtic fluid is derived muſt be obvious; and it only remains to examine the medium by which the volatile alkali is dephlogiſticated.

‘ In thoſe metals which are called *perfect*, ſo great is the firmneſs of texture, and ſo cloſe the connection of the earthy principle with the phlogiſton, that by means of fire alone theſe principles cannot be diſunited: but when diſſolved by acid menſtrua, they muſt neceſſarily loſe a portion of their phlogiſton; and therefore, when afterwards precipitated by alkalies which cannot ſupply the loſs, they fall down in a calcined ſtate, though they attract phlogiſton ſo ſtrongly, that they can be reduced to a metallic ſtate, merely by an intenſe heat penetrating the veſſels. It may therefore be laid down as a fundamental poſition, that gold is calcined by ſolution.

1121 Volatile alkali the cauſe of the exploſion.

“ Let us now conſider the conſequence of expoſing the powder conſiſting of calx of gold and volatile alkali intimately united, to an heat gradually increaſed. The calx which is united with the volatile alkali, by the aſſiſtance of a gentle heat, ſeizes its phlogiſton; and when this is taken away, the reſiduum of the ſalt is inſtantaneouſly expanded into the form of an elaſtic fluid, which is performed with ſo much violence, that the air muſt yield a very acute ſound.”

1122 Volatile alkali exhibits a flaſh when thrown into a hot crucible.

Our author proceeds to explain this phenomenon upon the principles aſſumed by him and Mr Scheele, of heat being a compoſition of light, and the phlogiſton or principle of inflammability; but as this hypotheſis is by no means ſatisfactory, we ſhall omit his reaſoning founded upon it: That the volatile alkali, however, is really capable of producing a flaſh is eaſily proved, becauſe it exhibits one when thrown into a

1123 Great quantity of elaſtic fluid produced by aurum fulminans.

hot crucible. A ſingle cubic inch of gun-powder generates about 244 of elaſtic fluid; but the ſame quantity of aurum fulminans yields at leaſt four times as much; and hence we may eaſily underſtand the difference in their exploſive force.

“ That careful calcinations ſhould deſtroy the ful-

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Gold.

minating property, is not to be wondered at, as the volatile alkali is the indiſpenſible material cauſe; but, the peculiar alacrity which it acquires before the exploſive force is totally extinguiſhed, depends upon the nature of the materials, and of the operation. Thus the heat, when inferior to that neceſſary for fulmination, acts upon both the principles of the aurum fulminans, it prepares the metallic calx for a more violent attraction for phlogiſton; it alſo acts upon the phlogiſton of the volatile alkali, and leſſens its connection; which two circumſtances muſt tend to the union producing the exploſion. But this effect has a maximum; and at this period the ſlighteſt friction ſupplies the defect of neceſſary heat, and produces the fulmination. The calcined gold alſo ſeems to collect and fix the matter of heat, though ſtill inſufficient by means of its phlogiſton, in a certain degree; ſo that by means of friction, though but very ſlight, it becomes capable of exerting its force; but when the heating is ofen repeated without procuring its effect, the volatile alkali is by degrees diſſipated, and at length ſo much diminiſhed that the calx becomes inert.

1124 Why ſlight calcination deſtroys the fulminating property.

1125 Why it will not explode in cloſe veſſels.

"But if aurum fulminans is capable of producing ſuch a prodigious quantity of elaſtic fluid, how does it happen that it remains mute and inert when reduced in cloſe veſſels? Of this the reaſon may be, that every elaſtic fluid, in the act of breaking forth, requires a ſpace to expand in; and if this be wanting, it remains fixed. Taking this for granted, a calx of gold cannot be reduced in cloſe veſſels either by heat or by the phlogiſton of volatile alkali; for in either caſe it muſt evolve its elaſtic fluid, which by ſuppoſition it cannot do. Nothing remains to ſolve this difficulty but the ignition of the ſurrounding metal; by means of which the calx, in virtue of its ſuperior attraction, ſeizes the phlogiſton of the metal, which that ſubſtance here, as well as in other inſtances, is capable of loſing without the eruption or abſorption of any fluid whatever."

1126 Mr Bergman's opinions of the fublimation of other calces.

Several chemiſts have aſſerted, that the calces of copper or ſilver may be made to fulminate like that of gold. But Mr Bergman informs us, that theſe experiments never ſucceeded with him; "ſo (ſays he) they have either been ſilent upon ſome circumſtances neceſſary in the operation, or perhaps have been deceived by the detonation of nitrum flammans, or ſome other accidental occurrence. It is not ſufficient for the volatile alkali to adhere to the precipitate; for platina thrown down by this alkali retains a portion of it very obſtinately, but yet does not fulminate on the expoſure of fire.—Beſides the preſence of volatile alkali, it ſeems to be neceſſary that the metallic calx ſhould be reducible by a gentle heat, in order to decompoſe it; but every exploſion is not to be derived from the ſame cauſes; nay, in this reſpect, aurum fulminans, gun-powder, and pulvis fulminans, differ very much, though they agree in ſeveral particulars." Of late, however, it has been found that the calx of ſilver may be made to fulminate in a manner ſtill more extraordinary than that of gold. See the next article.

1127 Solution of gold by hepar ſulphuris.

If gold is melted with an hepar ſulphuris, compoſed of equal parts of ſulphur and fixed alkaline ſalt, the metal readily unites with it into an uniform maſs, capable of diſſolution in water without any ſeparation of its parts. The ſolution, beſides a nauſeous taſte from the ſulphur, has a peculiar penetrating bitterneſs, not diſcoverable in any other metalline ſolution made by the ſame means.

Gold

Though the compoſitions of ſulphur and alkali ſeem to unite more intimately with gold than any other metal, their affinity with it is but ſlight; copper, or iron, added to the matter in fuſion, diſunite, and precipitate the gold. The metal thus recovered, and purified by the common proceſſes, proves remarkably paler-coloured than at firſt. In an experiment related by Dr Brandt, in the Swediſh Memoirs, the purified gold turned out nearly as pale as ſilver, without any diminution of weight.

1128 Medicinal virtues of gold.

Gold has been thought to be poſſeſſed of many extraordinary virtues as a medicine; which, however, are long ago determined to be only imaginary. It is not indeed very eaſy to prepare this metal in ſuch a manner that it can be ſafely taken into the human body. The ſolution in aqua-regia is poiſonous; but if any eſſential oil is poured on this ſolution, the gold will be ſeparated from the acid, and united to the eſſential oil; with which, however, it contracts no laſting union, but in a few hours ſeparates in bright yellow film to the ſides of the glaſs. Vitriolic ether diſſolves the gold more readily and perfectly than the common eſſential oils; and keeps it permanently ſuſpended, the acid liquor underneath appearing colourleſs. The yellow ethereal ſolution poured off, and kept for ſome time in a glaſs ſtopt with a cork, ſo that the ſpirit may ſlowly exhale, yields long, tranſparent, priſmatic cryſtals, in ſhape like thoſe of nitre, and yellow like topaz. What the nature of theſe cryſtals is, either as to medicinal effects, or other purpoſes, is as yet unknown. 1129 Etheral ſolution.

Rectified ſpirit of wine mingles uniformly with the ſolution of gold made in acids: if the mixture is ſuffered to ſtand for ſome days in a glaſs ſlightly covered, the gold is by degrees revived, and ariſes in bright pellicles to the ſurface. Groſſer inflammable matters, wine, vinegar, ſolutions of tartar, throw down the gold, in its metallic form, to the bottom. Gold is the only metal which is thus ſeparable from its ſolution in acids by theſe ſubſtances; and hence gold may be purified by theſe means from all admixtures, and ſmall proportions of it in liquors readily diſcovered.

1130 Colour of gold reſtored.

When the colour of gold is by any means rendered pale, it may be recovered again by melting it with copper, and afterwards ſeparating the copper; or by a mixture of verdigris and ſal ammoniac with vitriol or nitre. The colour is alſo improved by fuſion with nitre, injecting ſal ammoniac upon it in the fuſion, quenching it in urine, or boiling it in a ſolution of alum. When borax is uſed as a flux, it is cuſtomary to add a little nitre or ſal ammoniac, to prevent its being made pale by the borax. Juncker reports, that by melting gold with four times its weight of copper, ſeparating the copper by aquafortis unpurified, then melting the gold with the ſame quantity of freſh copper, and repeating this proceſs eight or nine times, the gold becomes at length of a deep red colour, which ſuſtains the action of lead, antimony, and aquafortis.

§ 2.

§. 2. SILVER.

1131 *Ductility of ſilver.* THIS, next to gold, is the moſt perfect, fixed, and ductile of all the metals. Its ſpecific gravity is to that of water nearly as 11 to 1. A ſingle grain has been drawn into a wire three yards long, and flatted into a plate an inch broad. In common fire it ſuffers no diminution of its weight; and, kept in the vehement heat of a glaſs-houſe for a month, it loſes no more than one ſixty-fourth. In the focus of a large burning-glaſs, it ſmokes for a long while, then contracts a greyiſh aſh on the ſurface, and at length is totally diſſipated.

Silver is ſomewhat harder and more ſonorous than gold, and is fuſible with a leſs degree of heat. The tenacity of its parts alſo is nearly one half leſs than that of gold; a ſilver wire of $\frac{1}{10}$ of an inch diameter being unable to bear more than 270 pounds.

Mercury unites very readily with ſilver-leaf, or with the calx of ſilver precipitated by copper; but does not touch the calces precipitated by alkaline
1132 *Effects of ſulphur on it.* ſalts. The vapours of ſulphureous ſolutions ſtain ſilver yellow or black. Sulphur, melted with ſilver, debaſes its colour to a leaden hue, renders it more eaſily fuſible than before, and makes it flow ſo thin as to be apt in a little time to penetrate the crucible: in a heat juſt below fuſion, a part of the ſilver ſhoots up, all over the ſurface, into capillary efflореſcence. Aquafortis does not act upon ſilver in this compound; but fixed alkaline ſalts will abſorb the ſulphur, and from a hepar ſulphuris, which, however, is capable of again diſſolving the metal. If the ſulphurated ſilver is mixed with mercury ſublimate, and expoſed to the fire, the mercury of the ſublimate will unite with the ſulphur, and carry it up in the form of cinnabar, whilſt the marine acid of the ſublimate unites with the ſilver into a luna cornea, which remains at the bottom of the glaſs. Fire alone is ſufficient, if continued for ſome time, to expel the ſulphur from ſilver.

From the baſer metals, ſilver is purified by cupel-
1133 *Purification.* lation with lead. (See REFINING.) It always retains, however, after that operation, ſome ſmall portion of copper, ſufficient to give a blue colour to volatile ſpirits, which has been erroneouſly thought to proceed from the ſilver itſelf. It is purified from this admixture by melting it twice or thrice with nitre and borax. The ſcoria, on the firſt fuſion, is commonly blue; on the ſecond, green; and on the third, white, which is a mark of the purification being com-
1134 *Luna cornea reduced.* pleted.

The moſt effectual means, however, of purifying ſilver, is by reviving it from luna cornea; becauſe ſpirit of ſalt will not precipitate copper as it does ſilver. The ſilver may be recovered from luna cornea, by fuſion with alkaline and inflammable fluxes; but, in theſe operations, ſome loſs is always occaſioned by the diſſipation of part of the volatile
1135 *Mr Margraaf's method.* calx, before the alkali or metal can abſorb its acid. Mr Margraaf has diſcovered a method of recovering the ſilver with little or no loſs; mercury aſſiſted by volatile ſalts, imbibing it by trituration without heat. One part of luna cornea, and two of volatile ſalt, are to be ground together in a glaſs-mortar, with ſo much water as will reduce them to the conſiſtence of a thin paſte, for a quarter of an hour, or more; five parts of pure quickſilver are then to be added, with a little more water, and the triture to be continued for ſome hours. A fine amalgam will thus be obtained; which is to be waſhed with freſh parcels of water, as long as any white powder ſeparates. Nearly the whole of the ſilver is contained in the amalgam, and may be obtained perfectly pure by diſtilling off the mercury. The white powder holds a ſmall proportion ſeparable by gentle ſublimation; the matter which ſublimes is nearly ſimilar to mercurius dulcis.

The colour of ſilver is debaſed by all the metals, and its malleability greatly injured by all but gold and copper. The Engliſh ſtandard ſilver contains one part of copper to twelve and one-third of pure ſilver.
This metal diſcovers in ſome circumſtances a great attraction for lead; though it does not retain any of that metal in cupellation. 1136 *Attraction for lead.* If a mixture of ſilver and copper be melted with lead in certain proportions, and the compound afterwards expoſed to a moderate fire, the lead and ſilver will melt out together, bringing very little of the copper with them; by this means ſilver is often ſeparated from copper in large works. The effect does not wholly depend upon the different fuſibility of the metals; for if tin, which is ſtill more fuſible than lead, be treated in the ſame manner with a mixture of ſilver and copper, the three ingredients are found to attract one another ſo ſtrongly as to come all into fuſion together. Again, if ſilver be melted with iron, and lead added to the mixture, the ſilver will forſake the iron to unite with the lead, and the iron will float by itſelf on the ſurface.

1137 *Whitened externally.* Silver is purified and whitened externally by boiling in a ſolution of tartar and common ſalt. This is no other than an extraction of the cupreous particles from the ſurface of the ſilver, by the acid of the tartar acuated by the common ſalt.

1138 *Fulminating ſilver.* M. Berthollet has lately diſcovered a method of imparting to the calx of ſilver a fulminating property, and that much more terrible than fulminating gold it-
1139 *How prepared.* ſelf. His receipt for making it is, "Take cupelled ſilver, and diſſolve it in the nitrous acid; precipitate the ſilver from the ſolution by lime-water, decant the clear liquor, and expoſe the precipitate three days to the open air. Mix this dried precipitate with the cauſtic volatile alkali, it will turn black; and when dried in the air, after decanting the clear liquor, is the fulminating powder required."

The properties of this powder are ſaid to be ſo extraordinary, that it is impoſſible to imagine how any part of it can ever be ſeparated from the reſt after it
1140 *Fulminates by the touch of any ſubſtance whether cold or hot.* is once prepared. To make this fulminate, it ſeems no ſenſible degree of heat is neceſſary, the contact of a cold body anſwering that purpoſe as well as any other. After it is once made, therefore, it muſt not be touched, but remain in the veſſel in which it is dried; and ſo violent is the exploſion, that it is dangerous to attempt it in larger quantities than a grain at a time.
1141 *Dangerous when more than a grain is fulminated at a time.* For the ſame reaſon it undoubtedly follows, that no more than a grain ought to be made at a time, or at leaſt in one veſſel, becauſe no part of it could ever afterwards be ſeparated from the reſt. We are told, that, "the wind having turned over a paper containing ſome atoms of this powder," (we ought to have

Silver.

been informed how the atoms came there, confidering what we have juft now related,) "the portion touched by the hand fulminated, and of courfe that which fell upon the ground. A drop of water which fell upon this powder caufed it to fulminate. A fingle grain of fulminating filver, which was in a glafs cup, reduced the glafs to powder, and pierced feveral doubles of paper.

1142 Fulminating cryftals.

"If the volatile alkali, which has been employed with the above powder, be put into a thin glafs matrafs and boiled, then, on ftanding in the cold, fmall cryftals will be found fublimed on the interior fides of the veffel, and covering the liquor. On touching one of thefe cryftals the matrafs will be burft with confiderable explofion.

1143 Cautions to be ufed in preparing it.

"The dangerous properties of this powder fuggeft the neceffity of not preparing it but when the face is covered with a mafk with glafs eyes; and to avoid the rupture of the glafs cups, it is prudent to dry the fulminating filver in fmall metalline veffels." To this we may add, that as the powder does not fulminate when wet, it may in that ftate be put up in very fmall quantities on paper, to be fulminated afterwards as occafion offers. This will perhaps account for the appearance of the few atoms abovementioned on the paper which the wind overturned.

1144 Abfurd theory of the antiphlogiftons.

With regard to the caufe of this extraordinary fulmination we can fay nothing fatisfactory; the following curious reafon is affigned by the antiphlogiftons; which at once fhows the futility of their theory, and fets in a very ridiculous light the hard words with which they would obfcure the fcience of chemiftry. "The oxygenous principle * (fay they) unites with the hydrogenous principle † of the volatile alkali, and form water in a vaporous ftate. This water (in a vaporous ftate) being inftantaneoufly *thrown into a ftate of vapour*, poffeffing elafticity and expanfive force, is the principal caufe of this phenomenon, in which the *azotic* ‡ air which is difengaged from the volatile alkali, with its whole expanfile power, has a great fhare."

* Dephlogifticated air.
† Inflammable air.
‡ Phlogifticated air.

1145 Remarks on this and other theories.

On this, as well as other theories, in which elaftic fluids are alleged to be the caufe of explofions, it is obvious to remark, that fhould we allow this to be the cafe, we are utterly at a lofs to find a fource of heat fufficient to rarefy the vapour to fuch a degree as is neceffary for producing the effect afcribed to it. In the prefent cafe, we can fcarce fuppofe a grain weight of metalline calx, already dry, to contain as much either of fire or water as is neceffary to produce the effect; nor can we explain why the touch of any cold body, and which may be fuppofed to contain lefs fire than the calx itfelf, fhould produce fuch an effect. As to the oxygenous and hydrogenous principles, they were there before the touch, and ought to have produced their effects, not to mention that the water produced by them could not have amounted to the thoufandth part of a grain. It is much more probable, therefore, that the whole is to be confidered as an effect of electricity, though we cannot tell how the fluid comes here to be excited in fuch a violent manner.

1146 The phenomenon probably owing to electricity.

§ 3. *Copper.*

This is one of thofe metals which, from their deftructibility by fire, and contracting ruft in the air, are called *imperfect*. Of thefe, however, it is the moft perfect and indeftructible. It is of a reddifh colour when pure; eafily tarnifhes in a moift air, and contracts a green ruft. It is the moft fonorous of all the metals, and the hardeft and moft elaftic of all but iron. In fome of its ftates, copper is as difficultly extended under the hammer as iron, but always proves fofter to the file; and is never found hard enough to ftrike a fpark with flint or other ftones; whence its ufe for chiffels, hammers, hoops, &c. in the gunpowder works. When broke by often bending backwards and forwards, it appears internally of a dull red colour without any brightnefs, and of a fine granulated texture refembling fome kinds of earthen ware. It is confiderably ductile, though lefs fo than either gold or filver; and may be drawn into wire as fine as hair, or beaten into leaves almoft as thin as thofe of filver. The tenacity of its parts is very confiderable; for a copper wire of $\frac{1}{10}$ of an inch diameter will fupport a weight of $299\frac{1}{4}$ pounds without breaking. The fpecific gravity of this metal, according to Dr Lewis, is to that of water as 8.830 to 1.

Copper.

1147 Always fofter than iron.

Copper continues malleable when heated red; in which refpect it agrees with iron; but is not, like iron, capable of being welded, or having two pieces joined into one. It requires for its fufion a ftronger heat than either gold or filver, though lefs than that requifite to melt iron. When in fufion, it is remarkably impatient of moifture; the contact of a little water occafioning the melted copper to be thrown about with violence, to the great danger of the by-ftanders. It is, neverthelefs, faid to be granulated in the brafs-works at Briftol, without explofion or danger, by letting it fall in little drops, into a large ciftern of cold water covered with a brafs-plate. In the middle of the plate is an aperture, in which is fecured with Sturbridge clay a fmall veffel, whofe capacity is not above a fpoonful, perforated with a number of minute holes, through which the melted copper paffes. A ftream of cold water paffes through the ciftern. If fuffered to grow hot, the copper falls liquid to the bottom, and runs into plates.

1148 How granulated.

Copper, in fufion, appears of a bluifh green colour, nearly like that of melted gold. Kept in fufion for a long time, it becomes gradually more and more brittle; but does not fcorify confiderably, nor lofe much of its weight. It is much lefs deftructible than any of the imperfect metals, being very difficultly fubdued even by lead or bifmuth. If kept in a heat below fufion, it contracts on the furface thin powdery fcales; which, being rubbed off, are fucceeded by others, till the whole quantity of the metal is thus changed into a fcoria or calx, of a dark reddifh colour. This calx does not melt in the ftrongeft furnace fires; but, in the focus of a large burning mirror, runs eafily into a deep red, and almoft opaque, glafs. A flaming fire, and ftrong draught of air over the furface of the metal, greatly promote its calcination. The flame being tinged of a green, bluifh, or rainbow colour, is a mark that the copper burns.

1149 Calcined.

This metal is very readily foluble by almoft all faline fubftances; even common water, fuffered to ftand long in copper-veffels, extracts fo much as to gain a coppery tafte. It is obfervable, that water is much more impregnated with this tafte, on being fuffered to ftand in the cold, than if boiled for a longer time in the veffel. The fame thing happens in regard to the mild vegetable acids. The confectioners prepare the moft acid fyrups, even thofe of lemons and oranges, by

1150 Solubility.

Copper. by boiling in clean copper-veſſels, without the preparations receiving any ill taſte from the metal; whereas, either the juices themſelves, or the ſyrups made from them, if kept cold in copper veſſels, ſoon become impregnated with a diſagreeable taſte, and with the pernicious qualities of the copper.

1151 Altered by combination with vegetable acids.

By combination with vegetable acids, copper becomes in ſome reſpects remarkably altered. Verdigris, which is a combination of copper with a kind of acetous or tartareous acid, is partially ſoluble in diſtilled vinegar; the reſiduum, on being melted with borax and linſeed oil, yields a brittle metallic ſubſtance, of a whitiſh colour, not unlike bell-metal. The copper alſo, when revived from the diſtilled verdigris, was found by Dr Lewis to be different from the metal before diſſolution; but neither of theſe changes have yet been ſufficiently examined.

1152 Amalgamation with mercury.

Copper, in its metallic ſtate, is very difficultly amalgamated with mercury; but unites with it more eaſily if divided by certain admixtures. If mercury and verdigris be triturated together with common ſalt, vinegar, and water, the copper in the verdigris will be imbibed by the mercury, and form with it, as Boyle obſerves, a curious amalgam, at firſt ſo ſoft as to receive any impreſſion, and which, on ſtanding, becomes hard like brittle metals. Braſs leaf likewiſe gives out its copper to mercury, the other ingredient of the braſs ſeparating in the form of powder.

1153 Dr Lewis's method.

Eaſier methods of amalgamating copper are publiſhed by Dr Lewis in his notes on Wilſon's Chemiſtry, p. 432. His receipts are,—"Diſſolve ſome fine copper in aquafortis: when the menſtruum will take up no more of the metal, pour it into an iron mortar, and add ſix times the weight of the copper, of mercury, and a little common ſalt: grind the whole well together with an iron peſtle; and, in a little time, the copper will be imbibed by the mercury, and an amalgam formed, which may be rendered bright by waſhing it well with repeated affuſions of water.

"*Another method.* Take the muddy ſubſtance which is procured in the poliſhing of copper plates with a pumice ſtone, and grind it well with a ſuitable portion of mercury, a little common ſalt, and ſome vinegar, in an iron mortar, (a marble one will do, if you make uſe of an iron peſtle), till you perceive the mercury has taken up the copper." The copper recovered from theſe amalgams retains its original colour, without any tendency to yellow. Even when braſs is made uſe of for making the amalgam, the recovered metal is perfect red copper; the ingredient from which the braſs received its yellowneſs being, as above obſerved, ſeparated in the amalgamation.

1154 Braſs, how prepared.

Copper is the baſis of ſeveral metals for mechanic uſes; as braſs, prince's metal, bell-metal, bath-metal, white copper, *&c.* Braſs is prepared from copper and calamine, with the addition of powdered charcoal, cemented together, and at laſt brought into fuſion. The calamine is to be previouſly prepared by cleanſing it from adhering earth, ſtone, or other matters; by roaſting, or calcining it; and by grinding it into a fine powder. The length of time, and degree of heat, requiſite for the calcination of the calamine, are different according to the qualities of that mineral. The calamine, thus calcined, cleanſed, and ground, is to be mixed with about a third or fourth part of charcoal duſt, or powdered pit-coal, as is done in ſome parts of England. The malleability of the baſis is diminiſhed by the uſe of pit-coal, which is therefore only employed for the preparation of the coarſer kinds. To this compoſition of calamine and coal, ſome manufacturers add common ſalt, by which the proceſs of making braſs is ſaid to be haſtened. In Goſlar, where the cadmia adhering to the inſides of the furnaces is uſed inſtead of the native calamine, a ſmall quantity of alum is added, by which they pretend the colour of the braſs is heightened. With this compoſition, and with thin plates or grains of copper, the crucibles are to be nearly filled. The proportion of the calamine to the copper varies according to the richneſs of the former, but is generally as three to two. The copper muſt be diſperſed through the compoſition of calamine and coal; and the whole muſt be covered with more coal, till the crucibles are full. The crucibles, thus filled, are to be placed in a furnace ſunk in the ground, the form of which is that of the fruſtum of a hollow cone. At the bottom of the furnace, or greater baſis of the fruſtum, is a circular grate, or iron-plate. This plate is covered with a coat of clay and horſe-dung, to defend it from the action of the fire; and pierced with holes, through which the air maintaining the fire paſſes. The crucibles ſtand upon the circular plate, forming a circular row, with one in the middle. The fuel is placed betwixt the crucibles, and is thrown into the furnace at the upper part of it, or the leſſer baſis of the fruſtum. To this upper part or mouth of the furnace is fitted a cover made of bricks or clay, kept together with bars of iron, and pierced with holes. This cover ſerves as a regiſter. When the heat is to be increaſed, the cover muſt be partly or entirely taken off, and a free draught is permitted to the external air, which paſſes along a vault under-ground to the aſh-hole, through the holes in the circular grate or plate, betwixt the crucibles, and through the upper mouth, along with the ſmoke and flame, into an area where the workmen ſtand, which is covered with a large dome or chimney, through which the ſmoke and air aſcend. When the heat is to be diminiſhed, the mouth of the furnace is cloſed with the lid; through the holes of which the air, ſmoke, and flame paſs. The crucibles are to be kept red-hot during eight or ten hours; and in ſome places much longer, even ſeveral days, according to the nature of the calamine. During this time, the zinc riſes in vapour from the calamine, unites with the copper, and renders that metal conſiderably more fuſible than it is by itſelf. To render the metal very fluid, that it may flow into one uniform maſs at the bottom, the fire is to be increaſed a little before the crucibles are taken out, for pouring off the fluid metal into moulds. From 60 pounds of good calamine, and 40 of copper, 60 pounds of braſs may be obtained, notwithſtanding a conſiderable quantity of the zinc is diſſipated in the operation. The quantity of braſs obtained has been conſiderably augmented ſince the introduction of the method now commonly practiſed, of granulating the copper; by which means a larger ſurface of this metal is expoſed to the vapour of zinc, and conſequently leſs of that vapour eſcapes. To make the finer and more malleable kinds of braſs, beſides the choice of pure calamine and pure copper, Copper.

Copper. ſome manufacturers cement the braſs a ſecond time with calamine and charcoal; and ſometimes add to it old braſs, by which the new is ſaid to be meliorated.

Braſs is brittle when hot; but ſo ductile when cold, that it may be drawn into very fine wire, and beat into very thin leaves. Its beautiful colour, malleability, and its fuſibility, by which it may be eaſily caſt into moulds, together with its being leſs liable to ruſt than copper, render it fit for the fabrication of many utenſils.

Although zinc be fixed to a certain degree in braſs, by the adheſion which it contracts with the copper; yet when braſs is melted, and expoſed to a violent fire, during a certain time, the zinc diſſipates in vapours, and even flames away, if the heat be ſtrong enough; and if the fire is long enough continued, all the zinc will be evaporated and deſtroyed, ſo that what remains
2d 1154 is copper.

Prince's metal. Prince's metal is made by melting zinc in ſubſtance with copper; and all the yellow compound metals prepared in imitation of gold are no other than mixtures of copper with different proportions of that ſemimetal, taken either in its pure ſtate, or in its natural ore calamine, with an addition ſometimes of iron-filings, *&c.* Zinc itſelf unites moſt eaſily with the copper; but calamine makes the moſt ductile compound, and gives the moſt yellow colour. Dr Lewis obſerves, that a little of the calamine renders the copper pale; that when it has imbibed about $\frac{1}{17}$ its own weight, the colour inclines to yellow; that the yellowneſs increaſes more and more, till the proportion comes to almoſt one half; that on further augmenting the calamine, the compound becomes paler and paler, and at laſt white. The crucibles, in which the fuſion is performed in large works, are commonly tinged by
1155 the matter of a deep blue colour.

Bell-metal. Bell-metal is a mixture of copper and tin; and tho' both theſe metals ſingly are malleable, the compound proves extremely brittle. Copper is diſſolved by melted tin eaſily and intimately, far more ſo than by lead. A ſmall portion of tin renders this metal dull-coloured, hard, and brittle. Bell-metal is compoſed of about ten parts of copper to one of tin, with the addition commonly of a little braſs or zinc. A ſmall proportion of copper, on the other hand, improves the colour and conſiſtency of tin, without much injuring its ductility. Pewter is ſometimes made from one
1156 part of copper and twenty or more of tin.

Dr Lewis's obſervations on the ſpecific gravity of the metal. It has long been obſerved, that though tin is ſpecifically much lighter than copper, yet the gravity of the compound, bell-metal, is greater than that of the copper itſelf. The ſame augmentation of gravity alſo takes place where the lighter metal is in the greateſt proportion; a mixture even of one part of tin with two of copper, turning out ſpecifically heavier than pure copper. Moſt metallic mixtures anſwer to the mean gravity of the ingredients, or ſuch as would reſult from a bare appoſition of parts. Of thoſe tried by Dr Lewis, ſome exceeded the mean, but the greater number fell ſhort of it; tin and copper were the only ones that formed a compound heavier than the heavieſt
1157 of the metals ſeparately.

White copper. White copper is prepared by mixing together equal parts of arſenic and nitre, injecting the mixture into a red-hot crucible, which is to be kept in a moderate fire till they ſubſide, and flow like wax. One part of this mixture is injected upon four parts of melted copper, and the metal, as ſoon as they appear thoroughly united together, immediately poured out. The copper, thus whitened, is commonly melted with a conſiderable proportion of ſilver, by which its colour is both improved and rendered more permanent. The white copper of China and Japan appears to be no other than a mixture of copper and arſenic. Geoffroy relates, that, on repeated fuſions, it exhaled arſenical fumes, and became red copper, loſing with its whiteneſs, one ſeventh of its weight.

§ 4. *Iron.*

Iron. Iron is a metal of a greyiſh colour; ſoon tarniſhing in the air into a duſky blackiſh hue; and in a ſhort time contracting a yellowiſh, or reddiſh ruſt. It is the hardeſt of all metals: the moſt elaſtic; and, except- 1158
ing platina, the moſt difficult to be fuſed. Next to gold, iron has the greateſt tenacity of parts; an iron wire, the diameter of which is the tenth part of an inch, being capable of ſuſtaining 450 pounds. Next to tin, it is the lighteſt of all the metals, loſing between a ſeventh and eighth part of its weight when immerſed in water. When very pure, it may be drawn into wire as fine as horſe-hair; but is much leſs capable of being beaten into thin leaves than the other metals, excepting only lead, Tenacity of its parts.

Iron grows red-hot much ſooner than any other metal; and this, not only from the application of actual fire, but likewiſe from ſtrong hammering, friction, or other mechanic violence. It nevertheleſs melts the moſt difficultly of all metals except mangaueſe and platina; requiring, in its moſt fuſible ſtate, an intenſe, bright, white heat. When perfectly malleable, it is not fuſible at all by the heat of furnaces, without the addition or the immediate contact of burning fuel; and, when melted, loſes its malleability: all the common operations which communicate one of theſe qualities deprive it at the ſame time of the other; as if fuſibility and malleability were in this metal incompatible. When expoſed to the focus of a large burning mirror, however, it quickly fuſed, boiled, and emitted an ardent fume, the lower part of which was a true flame. At length it was changed into a blackiſh vitrified ſcoria. 1159

From the great waſte occaſioned by expoſing iron to a red but eſpecially to a white heat, this metal appears to be a combuſtible ſubſtance. This combuſtion is maintained, like that of all other combuſtible ſubſtances, by contact of air. Dr Hook, having heated a bar of iron to that degree called *white heat*, he placed it upon an anvil, and blowed air upon it by means of bellows, by which it burnt brighter and hotter. Expoſed to a white heat, it contracts a ſemivitreous coat, which burſts at times, and flies off in ſparkles. No other metallic body exhibits any ſuch appearance. On continuing the fire, it changes by degrees into a dark red calx, which does not melt in the moſt vehement heat procurable by furnaces, and, if brought into fuſion by additions, yields an opaque black glaſs. When ſtrongly heated, it appears covered on the ſurface with a ſoft vitreous matter like varniſh. In this ſtate, pieces of it cohere; and, on being Iron a combuſtible ſubſtance.

Iron.

1160 The only metal capable of being welded. being hammered together, weld or unite, without discovering a juncture. As iron is the only metal which exhabits this appearance in the fire, so it is the only one capable of being welded. Those operations which prevent the superficial scorification, deprive it likewise of this valuable property: which may be restored again, by suffering the iron to resume its vitreous aspect; and, in some measure, by the interposition of foreign vitrescible matters; whilst none of the other metals will unite in the smallest degree, even with its own scoria.

1161 Contracts in fusion. Iron expands the least of all metals by heat. In the act of fusion, instead of continuing to expand, like the other metals, it shrinks; and thus becomes so much more dense, as to throw up such part as is unmelted to the surface; whilst pieces of gold, silver, copper, lead, or tin, put into the respective metals in fusion, sink freely to the bottom. In its return to a consistent state, instead of shrinking like the other metals, it expands; sensibly rising in the vessel, and assuming a convex surface, while the others become concave. This property, first observed by Raumur, excellently fits it for receiving impressions from moulds. By the increase of bulk which the metal receives in congelation, it is forced into the minutest cavities, so as to take the impression far more exactly than the other metals which shrink.

1162 Dissolved by all metals except lead and mercury. Iron is dissolved by all the metals made fluid, except lead; though none of them act so powerfully upon it as gold: but, as Cramer observes, if the iron contains any portion of sulphur, it can scarcely be made to unite at all with gold.

Among the semimetallic bodies, it is averse to an union with mercury; no method of amalgamating these two having yet been discovered; though quicksilver, in certain circumstances, seems in some small degree to act upon it. A plate of tough iron, kept immersed in mercury for some days, becomes brittle; and mercury will often adhere to and coat the ends of iron pestles used in triturating certain amalgams with saline liquors. Mr Jones has also discovered, that by plunging iron, while heated to an intense white heat, into mercury, the latter will adhere to the surface of the iron, and completely silver it over.

Next to mercury, zinc is the most difficultly combined with iron; not from any natural indisposition to unite, but from the zinc being difficultly made to sustain the heat requisite. The mixture is hard, somewhat malleable, of a white colour approaching to that of silver. Regulus of antimony, as soon as it melts, begins to act on iron, and dissolves a considerable quantity. If the regulus be stirred with a iron rod, it will melt off a part of it. Arsenic likewise easily mingles with iron, and has a strong attraction for it; forsaking all the other metals to unite with this. It renders the iron white, very hard, and brittle.

1163 Prussian blue. This metal is the basis of the fine blue pigment, called, from the place where it was first discovered, *Berlin* or *Prussian* blue. This colour was accidentally discovered about the beginning of the present century, by a chemist of Berlin, who, having successively thrown upon the ground several liquors from his laboratory, was much surprised to see it suddenly stained with a beautiful blue colour. Recollecting what liquors he had thrown out, and observing the same effects from a similar mixture, he prepared the blue for the use of painters; who found that it might be substituted to ultramarine, and accordingly have used it ever since.

Several chemists immediately endeavoured to discover the composition of this pigment; and in the year 1724 Dr Woodward published the following process, in the Philosophical Transactions, for making it. "Alkalize together four ounces of nitre, and as much tartar as is directed for charcoal (n° 779). Mix this alkali well with four ounces of dried bullocks blood; and put the whole in a crucible covered with a lid, in which there is a small hole. Calcine with a moderate heat, till the blood be reduced to a perfect coal; that is, till it emits no more smoke or flame capable of blackening any white bodies that are exposed to it. Increase the fire towards the end, so that the whole matter contained in the crucible shall be moderately, but sensibly, red. 1164 Dr Woodward's recept for.

"Throw into two pints of water the matter contained in the crucible, while yet red, and gave it half an hour's boiling: decant this first water; and pour more upon the black charry coal, till it becomes almost insipid. Mix together all these waters; and reduce them, by boiling, to about two pints.

"Dissolve also two ounces of martial vitriol, and eight ounces of alum, in two pints of boiling water. Mix this solution when hot with the preceding lixivium also hot. A great effervescence will then be made: the liquors will be rendered turbid; and will become of a green colour, more or less blue; and a precipitate will be formed of the same colour. Filtrate, in order to separate this precipitate; upon which pour spirit of salt, and mix them well together; by which means the precipitate will become of a fine blue colour. It is necessary to add rather too much of the salt than too little, and till it no longer increases the beauty of the precipitate. The next day wash this blue, till the water comes off from it insipid; and then gently dry it."

Mr Geoffroy was the first who gave any plausible theory of this process, or any rational means of improving it. He observes, that the Prussian blue is no other than the iron of the vitriol revived by the inflammable matter of the alkaline lixivium, and perhaps a little brightened by the earth of alum; that the green colour proceeds from a part of the yellow ferruginous clax, or ochre, unrevived, mixing with the blue; and that the spirit of salt dissolves this ochre more readily than the blue part; though it will dissolve that also by long standing, or if used in too large quantity. From these principles, he was led to increase the quantity of inflammable matter; that there might be enough to revive the whole of the ferruginous ochre, and produce a blue colour at once, without the use of the acid spirit. In this he perfectly succeeded; and found, at the same time, that the colour might be rendered of any degree of deepness, or lightness, at pleasure. If the alkali is calcined with twice its weight of dried blood, and the lixivium obtained from it poured into a solution of one part of vitriol to six of alum, the liquor acquires a very pale blue colour, and deposits as pale a precipitate. On adding more and more of a fresh solution of vitriol, the colour becomes deeper and deeper, almost to blackness. He imagines, with great probability, that the blue pigment, thus prepared, will prove more durable in the air, mingle more perfectly with other colours, and be 1165 Mr Geoffroy's theory.

less

Iron less apt to injure the lustre of such as are mixed with or applied in its neighbourhood, than that made in the common manner; the tarnish to which common Prussian blue is subject, seeming to proceed from the acid, which cannot be separated by any ablution.

1166 Amusing phenomenon in the preparation.

He takes notice of an amusing phenomenon which happens upon mixture. When the liquors are well stirred together; and the circular motion, as soon as possible, stopped; some drops of solution of vitriol, (depurated, by long settling), let fall on different parts of the surface, divide, spread, and form curious representations of flowers, trees, shrubs, flying insects, &c. in great regularity and perfection. These continue 10 or 12 minutes: and on stirring the liquor again, and dropping in some more of the solution of vitriol, are succeeded by a new picture.

1167 Mr Macquer's theory.

This theory is confirmed by Mr Macquer, in a Memoir printed in the year 1752. He observes, that the quantity of phlogiston communicated to the iron in this process is so great, as not only to cause the metal resist in a great measure the action of acids, and become totally unaffected by the magnet; but by a slight calcination it becomes entirely similar to other iron, and is at once deprived of its blue colour. He further observes, that fire is not the only means by which Prussian blue may be deprived of all the properties which distinguish it from ordinary iron. A very pure alkali produces the same effect. He has also discovered, that the alkali which has thus deprived the Prussian blue of all the properties which distinguish it from ordinary iron, becomes, by that operation, entirely similar to the phlogisticated alkali used for the preparation of Prussian blue.

1168 Phlogisticated alkali loses its alkaline properties.

By a more particular examination, he found, that the alkali might become perfectly saturated with the colouring matter; so that, when boiled on Prussian blue, it extracted none of its colour. When the salt was thus perfectly saturated, it seemed no longer to possess any alkaline qualities. If poured into a solution of iron in any acid, a single, homogeneous, and perfect precipitate, was formed; not green, as in Dr Woodward's process, but a perfect Prussian blue; which needed no acid to brighten its colour. A pure acid added to the alkali was not in the least neutralized, nor in the least precipitated the colouring matter. From hence Mr Macquer concludes, that, in the making of Prussian blue, vitriol is decomposed; because the iron has a strong attraction for the colouring matter, as well as the acid for the alkali; and the sum of the attraction of the acid to the alkali, joined to that of the iron for the colouring matter, is greater than the single attraction of the acid to the metal.

1169 Earths do not attract the colouring matter.

Another very important phenomenon is, that earths have not the same attraction for this colouring matter that metallic substances have. Hence, if an alkali saturated with this colouring matter be poured into a solution of alum, no decomposition is effected, nor any precipitate formed. The alum continues alum, and the alkali remains unchanged. From this experiment Mr Macquer concludes that alum does not directly contribute to the formation of the Prussian blue. The purpose he thinks it answers is as follows. Fixed alkaline salts can never be perfectly saturated with phlogistic matter by calcination; alkalies, therefore, though calcined with inflammable substances, so as to make a proper lixivium for Prussian blue, remain still alkaline. Hence, when mixed with a solution of green vitriol, they form, by their purely alkaline part, a yellow precipitate, so much more copious, as the alkali is less saturated with phlogiston. But nothing is more capable of spoiling the fine colour of the Prussian blue, than an admixture of this yellow precipitate: it is therefore necessary to add a quantity of alum, which will take up the greatest part of the purely alkaline salt, and of consequence the quantity of yellow ferruginous precipitate is much diminished. But the earth of alum, being of a fine shining white, does not in the least alter the purity of the blue colour, but is rather necessary to dilute it. From all this it follows, that it is a matter of indifference whether the green precipitate is to be again dissolved by an acid, or the alkaline part of the lixivium saturated with alum or with an acid, before the precipitate is formed. The latter indeed seems to be the most eligible method. 1170

Blue producible from other alkalies.

Most alkalies obtained from the ashes of vegetables, being combined, by their combustion, with a portion of inflammable matter, are capable of furnishing a quantity of Prussian blue, proportionable to the quantity of colouring matter they contain, even without the necessity of mixing them with a solution of iron; because they always contain a little of this metal dissolved, some of which may be found in almost all vegetables; therefore it is sufficient to saturate them with an acid. Henckel observed the production of this blue in the saturation of the fossile alkali, and recommended to chemists to inquire into its nature. 1171

Mr Scheele discovers the colouring matter of Prussian blue.

The theories of Geoffroy, Macquer, &c. however, with respect to Prussian blue, have now given place to that of Mr Scheele; who has examined the substance with the utmost care, and found the colouring matter to consist of an extremely volatile substance, capable of uniting with and neutralizing alkalies, but easily expelled from them by any other acid, even by that of 1172
fixed air. He begins his dissertation on this subject by observing, that the solution of alkali calcined with dried blood, which he calls *lixivium sanguinis*, by exposure to the air, loses its property of precipitating the iron of a blue colour; and that the precipitate thus obtained is entirely soluble in the acid. In order to determine whether the air had thus undergone any change, he put some newly prepared lixivium into a glass vessel well sealed with rosin; but after some time finding no change on the lixivium, or on the air contained in the vessel, he began to think that this might be occasioned by the absence of fixed air, which always 1173
abounds in the open atmosphere, though not in any confined portion of it, at least in an equal proportion. Having therefore filled a glass vessel with fixed air, he poured into it a little lixivium sanguinis; and next day found, that it threw down from green vitriol a precipitate entirely soluble in acids. With other acids he obtained no precipitate. 1174

Lixivium sanguinis loses its colouring property by exposure to the air.

Supposed to arise from the fixed air absorbed from the atmosphere.

The matter fixed by the addition of some green vitriol to the lixivium.

On inverting the experiment, and mixing some green vitriol with lixivium sanguinis, the mixture grew yellow; and he found this addition capable of fixing the colouring matter so that neither the acid of fixed air nor any other could expel it from the alkali. For having poured the mixture abovementioned into a solution of green vitriol, and afterwards supersaturated the

the lixivium with acid, he obtained a confiderable quantity of blue. To the fame lixivium fanguinis, in which a fmall quantity of green vitriol was diffolved, he afterwards added of the other acids fomewhat more than was neceffary for its faturation; and though this was done, a confiderable quantity of Pruffian blue was afterwards obtained.

1175
Calx of iron foluble in lixivium fanguinis;

Again, having precipitated a folution of green vitriol with alkali, and boiled the precipitate for fome minutes in lixivium fanguinis, part of it was diffolved: the filtered lixivium underwent no change when expofed to the open air or to the aerial acid, and precipitated the folution of vitriol of a blue; and though the lixivium was fuperfaturated with acid, and fome green vitriol added, a very beautiful Pruffian blue was obtained.

1176
But not when highly dephlogifticated.

This, however, will not hold when a perfectly dephlogifticated calx of iron is employed, of which none can be diffolved by the lixivium fanguinis; nor will any Pruffian blue be obtained by precipitating with lixivium fanguinis a perfectly dephlogifticated folution of iron in nitrous acid.

1177
The colouring matter taken up by the air after it has been expelled by acids.

To determine what had become of the colouring matter in thofe experiments where it feemed to have been diffipated, fome lixivium fanguinis was poured into a veffel filled with aerial acid. It was kept well corked during the night, and next day a piece of paper dipped in a folution of green vitriol was fixed to the cork, pencilling it over with two drops of a folution of alkali in water. The paper was thus foon covered with precipitated iron; and on being taken out two hours afterwards, and dipped in muriatic acid, became covered with moft beautiful Pruffian blue. The fame thing happened when lixivium fanguinis fuperfaturated with vitriolic acid was employed; for in this cafe alfo the air was filled with the colouring matter capable of being in like manner abforbed by the calx of iron. But though from thefe experiments it is plain that acids expel this colouring fubftance from the lixivium, a given quantity of air is only capable of receiving a certain quantity of it; for the fame mixture removed into another veffel imparts the colouring property to the air it contains according to its quantity. On putting perfectly dephlogifticated calx of iron upon the papers, no Pruffian blue was formed; but the muriatic acid diffolved the calx entirely.

1178
The colouring matter expelled by diftillation with vitriolic acid.

Our author having now affured himfelf that acids really attract the alkali more than the colouring matter, proceeded to try the effects of diftillation. Having therefore fuperfaturated fome lixivium fanguinis with vitriolic acid, he diftilled the mixture in a glafs retort with a gentle fire. When about one-third had paffed over, he changed the receiver, and continued the operation till one half was diftilled. The firft product had a peculiar tafte and fmell; the air in the receiver was filled with colouring matter, and the aqueous fluid was alfo ftrongly impregnated with it, as appeared by its forming a fine Pruffian blue with phlogifticated calx of iron. Part of it being expofed to the open air for fome hours, entirely loft its power, and the product of the fecond operation was no other than water mixed with a little vitriolic acid.

1179
Attemps to procure the colouring matter by itfelf.

The next ftep was to procure, if poffible, the colouring matter by itfelf; and this he attempted to obtain from the Pruffian blue, rather than the lixivium fanguinis, as he would thus not only avoid the troublefome calcination of the alkali and blood, but obtain the colouring matter im much larger quantity than could be done from the lixivium. On examining feveral kinds of this pigment, he found in them evident marks of fulphur, volatile alkali, vitriolic acid, and volatile fulphureous acid; all of which fubftances are to be found in the lixivium fanguinis as well as in that of foot, and adhere to the precipitate in the preparation of Pruffian blue. Finding, however, that he could not obtain his purpofe by any kind of analyfis of thefe by fire alone, he had recourfe to a neutral falt ufed by chemifts for difcovering iron in mineral waters. 1180

Neutral falt for difcovering iron in mineral waters.

This is formed by digefting cauftic fixed alkali on Pruffian blue, which effectually extracts the colour from it even in the cold, in a very fhort time, and being neutralized, may eafily be reduced into a dry form. But it is not entirely to be depended upon for this purpofe; for it always contains fome iron which indeed is the medium of its connection with the alkali. The lixivium fanguinis is preferable, though even this contains fome iron, as well as the lixivium of foot; our author's experiments, however, were made with the neutral falt, for the reafon already mentioned.

1181
Effects of diftilling this falt with oil of vitriol.

1 An ounce of the falt was diffolved in a glafs retort in four ounces of water, afterwards adding three drachms of concentrated vitriolic acid; and the mixture was diftilled with a gentle fire. The mafs grew thick as foon as it began to boil; from a great quantity of Pruffian blue, a quantity of the colouring matter appeared by the fmell to penetrate the lute: and part of it was abforbed by the air in the receiver, as in former experiments. The diftillation was continued till about an ounce had paffed into the receiver. The blue mafs remaining in the retort was put into a ftrainer, and a piece of green vitriol put into the liquid which paffed through; but by this laft no Pruffian blue was produced. The blue which remained in the filter was again treated with lixivium tartari: the folution freed from its ochre by filtration, and the clear liquor committed a fecond time to diftillation with vitriolic acid. Pruffian blue was again feparated, though in fmaller quantity than before, and the colouring matter came over into the receiver. After one third of the matter had paffed over, that which had been obtained by the firft diftillation was added to it, the Pruffian blue was feparated from the lixivium in the retort, and extracted a third time. Some Pruffian blue was formed again, though in much fmaller quantity; whence it is apparent that Pruffian blue may at laft be totally decompofed by means of alkali. Lime, or terra ponderofa, likewife extract the blue colour, and fhow the fame phenomena as alkali.

1182
Colouring matter unites with volatile alkali.

With volatile alkali a compound, confifting of the alkali, iron, and colouring matter, is formed, which fhows the fame phenomena with that formed with fixed alkali. By diftillation *per fe* after it has been diffolved in water, the liquor grows thick in confequence of a feparation of Pruffian blue, and volatile alkali paffes over into the receiver. This volatile fpirit is impregnated with the colouring matter; it is not precipitated by lime water; but green vitriol is precipitated by it; and on adding an acid, Pruffian blue is formed. If a piece of paper, dipped in a folution of green vitriol, be expofed to the vapour of this alkali, it is foon decompofed; and if the fame bepencilled over with muriatic acid, it inftantly becomes blue.

Iron.

blue. On expoſing the liquor to the open air, it all evaporates, leaving pure water behind.

1183
How to free the colouring matter perfectly from its vitriolic taint.

As in all the operations with vitriolic acid hitherto related, ſome ſmall quantity of it paſſes into the receiver, our author ſhows how to deprive the colouring matter, of that vitriolic taint. For this purpoſe nothing more is neceſſary than to put a little chalk into the matter, and rediſtil it with a very gentle heat; the acid unites with the chalk, and the colouring matter goes over in its greateſt purity.

1184
How to prevent the eſcape of the colouring matter thro' the lute.

In order to hinder, as much as poſſible, the eſcape of the volatile colouring matter through the lute, he makes uſe of a ſmall receiver, putting into it a little diſtilled water, and placing it ſo that the greater part ſhall be immerſed in cold water during the operation. The water impregnated with this colouring matter has a peculiar but not diſagreeable ſmell, a taſte ſomewhat approaching to ſweet, and warm in the mouth, at the ſame time exciting cough.

1185
This matter neither acid nor alkaline.

When rectified as above directed, it appears to be neither acid nor alkaline; for it neither reddens paper dyed with lacmus, nor does it reſtore the colour of ſuch paper after it has been made red; but it renders turbid the ſolutions of ſoap and hepar ſulphuris. The ſame liquor mixed with fixed alkali, though it contains a ſuperabundance of colouring matter, reſtores the blue colour of paper reddened by an acid. By diſtillation to dryneſs, there goes over a part of the colouring matter which diſengages itſelf from the alkali; the reſiduum is ſoluble in water, and has all the properties of the beſt lixivium ſanguinis; but, like the true lixivium, it is decompoſed by all the acids, even by that of fixed air.

1186
Forms a kind of ammoniacal ſalt with volatile alkali.

With cauſtic volatile alkali it forms a kind of ammoniacal ſalt; which, however, always ſmells volatile, though the colouring matter be in ever ſo great proportion. By diſtillation the whole inſtantly riſes, and nothing but pure water is left in the retort.

1187
Diſſolves magneſia alba.

Magneſia precipitated from Epſom ſalt by cauſtic volatile alkali, was diſſolved in the colouring matter by allowing them to ſtand together for ſeveral days in a warm cloſe bottle. On expoſure to the open air, the magneſia ſeparated from it by its ſuperior attraction for aerial acid, and formed on the ſurface of the water a pellicle like that of cream of tartar. This ſolution was likewiſe decompoſed by alkalies and lime-water.

1188
Very little terra ponderoſa.

The colouring matter diſſolves but a very ſmall quantity of terra ponderoſa, which may be afterwards precipitated by vitriolic and even by aerial acid.

1189
Diſſolves lime, but not clay.

Pure clay, or the baſis of alum, is not attacked by it. Lime is diſſolved in a certain quantity. The ſuperabundant portion ſhould be ſeparated by filtration; and as the liquor contains, beſides the combined lime, the portion which water itſelf is able to take up, in order to free it from this, preciſely the ſame quantity of water impregnated with aerial acid is to be added as is requiſite for precipitating an equal quantity of lime-water. The colouring matter, thus ſaturated with lime, is to be filtered again, and then to be preſerved in a well cloſed bottle to prevent the acceſs of fixed air. This ſolution is decompoſed by all the acids, and by the pure or cauſtic alkalies. By diſtillation the colouring matter riſes, and nothing but pure lime is left in the retort.—This ſolution of lime appears to our author to be ſo perfectly ſaturated, that he employed it in preference to any other in the experiments he made on metals, and which we are now about to relate.

Iron.

1190
The ſolution of lime the moſt proper for experiments on metals.

1191
Silver, quickſilver, and iron precipitated by the colouring matter.

From the trials made by Mr Scheele, it appears that the colouring matter has no effect upon any metal or metallic ſolution, excepting thoſe of ſilver and quickſilver in nitrous acid, and that of iron in fixed air. The firſt is precipitated in a white powder: the ſecond in a black one; and the third aſſumes a ſea-green colour, which afterwards turns to blue.

1192
Its effects on metallic calces;

With metallic calces it produces the following phenomena. 1. Gold precipitated by aerated alkali becomes white. 2. The fixed air is diſengaged from a precipitate of ſilver with a ſlight effervescence. 3. Calx of mercury is diſſolved, and yields cryſtals by gentle evaporation. 4. The calx of copper precipitated by aerated alkali effervesces, and aſſumes a faint citron colour. 5. Calx of iron precipitated from its ſolution in the vitriolic acid by the ſame alkali, effervesces, and aſſumes a dark blue colour. 6. Precipitated cobalt ſhows ſome ſigns of effervescence, and changes into a yellowiſh brown colour. The other calces are not acted upon.

1193
On metallic ſolutions.

The precipitating liquor abovementioned, poured into metallic ſolutions, produces the following appearances by means of double elective attraction. 1. Gold is precipitated of a white colour, but by adding a ſuperabundant quantity of the precipitating liquor the calx is rediſſolved. The ſecond ſolution is colourleſs as water. 2. Silver is precipitated in form of a white ſubſtance of the conſiſtence of cheeſe; by adding more of the liquor the precipitate is rediſſolved, and the ſolution is not decompoſed either by ſal ammoniac or marine acid. 3. Corroſive ſublimate apparently undergoes no change, though it is in reality decompounded; the calx being diſſolved in the colouring matter. Mercury diſſolved in the nitrous acid without heat, is precipitated in form of a black powder. 4. The ſolutions of tin and biſmuth are precipitated, but the calx is not acted upon by the colouring matter. 5. The ſame effects are produced on the ſolution of butter of antimony, as well as on that of well dephlogiſticated calx of iron. 6. Blue vitriol is precipitated of a yellow citron colour: if more of the precipitating liquor be added, the precipitate is rediſſolved into a colourleſs liquor and a colourleſs ſolution of the ſame calx is likewiſe obtained by volatile alkali. On adding more of the ſolution of blue vitriol, the ſolution likewiſe diſappears, and the liquor aſſumes a green colour. Acids diſſolve a portion of this precipitate, and the remainder is white. The muriatic acid diſſolves the precipitate completely, but lets it fall again on the addition of water. 7. The ſolution of white vitriol yields a white precipitate, which is not rediſſolved by addition of the precipitating liquor, but is ſoluble in acids. Theſe ſolutions ſmell like the colouring matter, which may be ſeparated from them by diſtillation. 8. Green vitriol is precipitated firſt of a yellowiſh brown colour, which ſoon changes to green, and then becomes blue on the ſurface. Some hours afterwards the precipitate ſubſides to the bottom of the veſſels, and then the whole mixture turns blue; but on adding any acid the precipitate becomes inſtantly blue. If a very ſmall quantity of green vitriol be put into the precipitating liquor, the

Iron.

the precipitate is entirely diffolved, and the whole affumes a yellow colour. 7. Solution of cobalt lets fall a brownifh yellow precipitate, which is not diffolved by adding more of the precipitating liquor, neither is it foluble in acids. By diftillation the colouring matter goes over into the receiver.

1194 Inveftigation of the conftituent part of the colouring matter.

Laftly, our author undertook an inveftigation of the conftituent parts of the colouring matter itfelf; and in this he fucceeded in fuch a manner as muft do honour to his memory, at the fame time that it promifes to be a real and lafting improvement to fcience, by fhowing a method of preparing this valuable pigment without that naufeous and horrid ingredient, blood, which is now ufed in great quantities for that purpofe.—His

1195 Inflammability of the colouring matter.

firft hint concerning this matter feems to have been taken from an obfervation of the air in his receiver accidentally taking fire from the neighbourhood of a candle. It burned without any explofion, and he was able to inflame it feveral times fucceffively. Wifhing to know whether any fixed air was contained in the colouring matter, he filled a retort half full of the liquor containing the colouring matter, and applying a receiver immediately after, gave the retort a brifk heat. As foon as the receiver was filled with thick vapours of the colouring matter, he disjoined it, and, inflaming the vapour by a little burning fulphur introduced into the cavity, found that the air which remained threw down a precipitate from lime-water.

1196 Aerial acid and phlogifton fuppofed to exift in it.

"Hence (fays he) it may be concluded, that the aerial acid (A) and phlogifton exift in this colouring matter."

1197 Pruffian blue yields volatile alkali by diftillation.

It has been afferted by feveral chemifts, that Pruffian blue by diftillation always yields volatile alkali.—To determine this, Mr Scheele prepared fome exceedingly pure from the precipitating liquor abovementioned and green vitriol; diftilling it afterwards in a glafs retort, to which he adapted a receiver containing a little diftilled water. The operation was continued till the retort became red-hot. In the receiver was found the colouring matter and volatile alkali, but no oil; the air in the receiver was impregnated with aerial acid, and the fame colouring matter; the refiduum was very black, and obeyed the magnet.

1198 Appearances on diftilling other precipitates thrown down by Pruffian alkali.

On fubftituting, inftead of the Pruffian blue, the precipitates of other metallic fubftances precipitated by the Pruffian alkali, the refults were: 1. The yellowifh brown precipitate of cobalt yielded the very fame products with Pruffian blue itfelf; the refiduum in the retort was black. 2. The yellow precipitate of copper took fire, and emitted, from time to time, fparks during the diftillation. It produced little colouring matter, but a greater quantity of aerial acid and volatile alkali than had been obtained by the former precipitates. A fublimate arofe in the neck of the retort, but in too fmall a quantity to make any experiment; the refiduum was reduced copper. 3. The precipitate of zinc yielded the fame with Pruffian blue. 4. That of filver yielded likewife volatile alkali and fixed air, but chiefly colouring matter; a fublimate containing fome filver arofe into the neck of the retort; the refiduum was reduced filver. 5. Calx of mercury cryftallized by means of the colouring matter, yielded fome of that matter, but fcarce any mark of volatile alkali. Some mercury, with a portion of the original compound, arofe in the neck of the retort.

1199 Ingredients contained in the colouring matter.

From thefe experiments Mr Scheele concluded, that the colouring matter of Pruffian blue was compofed of volatile alkali and an oily matter. He was confirmed in his conjecture, by obtaining Pruffian blue from green vitriol and fpirit of hartfhorn recently diftilled on the addition of muriatic acid. The fame product was obtained by means of the volatile fpirit drawn from ox's blood; fo that nothing now remained, but to imitate thefe natural proceffes by artificially combining the two ingredients together.

1200 Unfuccefsful attempts to prepare it artificially

For this purpofe he diftilled a mixture of volatile falt and unctuous oil; a mixture of the fame alkali with animal fat, and with oil of turpentine; a mixture of quick-lime, fal ammoniac, and auxunge, with others of a fimilar kind; but in vain. He began therefore to conclude, that as long as the volatile alkali contained any water, it could not enter into an union fufficiently intimate with the other principles to form the colouring matter; and finding alfo that the coal of blood, mixed with falt of tartar, yielded very good lixivium fanguinis, he concluded that no oily matter was neceffary for the fuccefs of the experiment.

1201 True method of forming it.

Thus was our author led to make the following decifive trials, which at once accomplifhed his purpofe, and fhowed the truth of the principles he had affumed. Three table-fponfuls of charcoal powder were mixed with an equal quantity of alkali of tartar, and the mixture put into a crucible. A fimilar mixture was put into another crucible, and both put into a fire, and kept red-hot for about a quarter of an hour. One of them was then taken out, and the contents thrown, while perfectly red-hot, into eight ounces of water. At the fame time he put into the other quantity an ounce of fal ammoniac in fmall pieces, agitating the whole brifkly together, and taking care at the fame time to pufh the fal ammoniac down towards the bottom of the crucible, which he replaced in the fire. Obferving in two minutes after, that no ammoniacal vapours arofe, the whole mafs was thrown, when red-hot, into eight ounces of water. The former lixivium, into which no fal ammoniac had been put, yielded no Pruffian blue; but the latter fhowed the fame phenomena with the beft lixivium fanguinis, and produced a great quantity of blue. By mixing plumbago with the alkali inftead of charcoal, a tolerable lixivium was obtained.

1202 Volatile alkali capable of uniting with phlogifton and fixed alkali, fo as to fuftain a great degree of heat.

"From thefe experiments (fays Mr Scheele), it appears, that the volatile alkali is capable of uniting with the carbonaceous matter, after it has been fubtilized by a ftrong heat; that it thus acquires the remarkable property of combining fo firmly with falt of tartar as to be able to fuftain the moft violent degree of heat; and when this lixivium is diffolved in water, there is obtained lixivium fanguinis, as it is called.—It is now eafy to explain what happens in the diftillation

Y

(A) This reafoning feems not to be fufficiently conclufive; for late experiments have fhown that inflammation is generally attended with the production of fixed air, which could not be proved to have an exiftence either in the materials or common atmofphere before.

Iron:

lation of Prussian blue, as well as that of the other abovementioned metallic precipitates.—In the distil-

1203 Appearances on distilling Prussian blue accounted for.

lation of Prussian blue, for instance, the calx of iron attracts a portion of phlogiston from the colouring matter. The aerial acid being thus disengaged, must go over into the receiver with the volatile alkali, which is set free at the same instant; but as the calx of iron in the heat of this distillation cannot unite with more phlogiston, a portion of the colouring matter, not decomposed, must likewise arise. If the calx of iron could combine with the whole of the phlogiston, there

1204 Colouring matter kept from rising by manganese.

would come nothing over into the reciever but aerial acid and volatile alkali. In order to prove this, I distilled a mixture of six parts of manganese finely powdered, and one part of pulverized Prussian blue, and obtained nothing but aerated volatile alkali, without the least mark of colouring matter."

1205 The colouring matter can separate only mercury and silver from their solution in nitrous acid.

Mr Scheele further remarks, that this colouring matter may probably be obtained in an aerial form, though he had not been able to do so. It is also worth notice, that, excepting the solutions of silver and mercury in nitrous acid, the colouring matter of Prussian blue is not able to decompose any other by a single elective attraction. Now, as we know that Prussian blue is not soluble in acids, it naturally follows, that the colouring matter has a greater affinity with iron than acids have, notwithstanding there is no precipitation perceived when this matter is mixed with the solution of vitriol of iron. "It may not be easy (says Mr Scheele) to give a satisfactory explanation of this phenomenon."

1206 Nitre alkalized by iron.

Iron deflagrates with nitre, and renders the salt alkaline and caustic. A part of the iron is thus rendered soluble, along with the alkalized salt. A mixture of equal parts of iron filings and nitre, injected into a strongly heated crucible, and, after the detonation, thrown into water, tinges the liquor of a violet or purplish blue colour. This solution, however, is not permanent. Though the liquor at first passes through a filter, without any separation of the iron; yet, on standing for a few hours, the metal falls to the bottom, in form of a brick-coloured powder. Volatile alkalies instantly precipitate the iron from this fixed alkaline solution.

1207 Iron filings and sulphur take fire spontaneously.

Iron readily unites with sulphur; and when combined with it, proves much easier of fusion than by itself. A mixture of iron filings and sulphur, moistened with water, and pressed down close, in a few hours swells and grows hot; and, if the quantity is large, bursts into flame.

By cementation with inflammable maters, iron imbibes a larger quantity of phlogiston; and becomes much harder, less malleable, and more fusible. It is then called *steel*. See METALLURGY, and STEEL.

§ 5. *LEAD.*

LEAD is a pale or livid-white metal, soon losing its brightness in the air, and contracting a blackish or greyish ash-colour. It is the softest and most flexible of all metallic bodies; but not ductile to any great de-

1208 Has very little tenacity.

gree, either in the form of wire or leaf; coming far short, in this respect, of all other metals. It has also the least tenacity of all metallic bodies; a leaden wire of $\frac{1}{10}$ of an inch diameter being capable of supporting only $29\frac{1}{4}$ pounds. Lead has, however, a considerable specific gravity; losing, when immersed in water, between $\frac{1}{11}$ and $\frac{1}{12}$ of its weight. It is of all metals the

Lead.

1209 Sheet-lead.

most fusible, excepting only tin and bismuth. The plumbers cast thin sheets of lead upon a table or mould, covered with a woollen, and above this with a linen, cloth, without burning or scorching the cloths. The melted lead is received in a wooden case without a bottom; which being drawn down the sloping table by a man on each side, leaves a sheet of its own width, and more or less thin according to the greater or less celerity of its descent. For thick plates, the table is covered over with moistened sand, and the liquid metal conducted evenly over it, by a wooden strike, which bears on a ledge at each side.

1210 Advantages of milled lead precarious.

Some have preferred, for mechanic uses, the milled lead, or flatted sheets, to the cast; as being more equal, smooth, and solid. But whatever advantage of this kind the milled sort may appear to have at first, they are not found to be very durable. When the lead is stretched between the rollers, its cavities must necessarily be enlarged. The particles of metal that may be squeezed into them can have no union or adhesion with the contiguous particles; and of consequence, must be liable, from bending, blows, jarrs, &c. to start out again, and leave the mass spongy and porous.

1211 Rendered sonorous.

Lead yields the dullest and weakest sound of all metallic bodies. Reaumer observes, that it is rendered sonorous by casting a small quantity into a spherical or elliptical segment, as in the bottom of an iron-laddle; from hence he conjectures, that the sound of the sonorous metals might be improved for the bells of clocks, &c. by giving them a similar form.

1212 Calcined.

Though this metal very soon loses its lustre, and tarnishes in the air, it resists much longer than iron or copper the combined action of air and water, before it is decomposed or destroyed; and hence it is exceedingly useful for many purposes to which these metals can by no means be applied. When just become fluid, lead looks bright like quicksilver; but immediately contracts a variously coloured pellicle on the surface. If this is taken off, and the fire continued, a fresh pellicle will always be formed, till the metal is by degrees changed into a dusky powder or calx. The injection of a little fat, charcoal-powder, or other inflammable matter, prevents this change, and readily revives the calx into lead again. It is said, that lead, recovered from its calces, proves somewhat harder and whiter than at first, as well as less subject to tarnish in the air.

1213 Minium.

The blackish calx or ashes of lead become of a very different appearance if the calcination is continued with a fire so moderate as not to melt them, and particularly if exposed to flame. By this treatment it is said that they become first yellow; then they are called *massicot* or *yellow lead*. This colour becomes gradually more and more intense, till at last the calx is of a deep red; and then is called *minium* or *red lead*; but it is certain, that by proper management this calx never becomes yellow, assuming a reddish colour from the beginning. Too great a heat makes it irrecoverably yellow. It can be more easily prepared without

exposure

Lead.

exposure to the flame. The degree of heat necessary for converting it into minium is between 600 and 700 of Fahrenheit.

1214 Litharge. If instead of keeping this calx in a continued moderate heat, it be suddenly fused, the matter then puts on a foliated appearance, changing to a dull kind of brick-colour when powdered, and is then called *litharge*. Most of this substance is produced by refining silver with lead (see REFINING): and is of two kinds, white and red. These two are distinguished by the names of *litharge of gold*, and *litharge of silver*. The most perfect is that called *litharge of gold*: the pale sort contains a considerable proportion of lead in its metallic state; and even the highest coloured litharge is seldom free from a little metallic lead, discoverable and separable by melting the mass in a crucible; when the lead subsides to the bottom.

1215 Phenomena with other metals. Lead mingles in fusion with all the metals except iron, with which it refuses any degree of union as long as the lead preserves its metallic form. On continuing the fire, the lead, scorifying or calcining, absorbs the phlogistic principle of the iron, and consequently promotes the calcination of that metal; both being at length reduced to calces. The fusible calx of lead easily unites with the calx of iron, and both melt together into an opaque brown or blackish glass. Copper does not unite with melted lead till the fire is raised so high as to make the lead smoke and boil, and of a bright red heat. Pieces of copper, now thrown in, soon dissolve and disappear in the lead: the mixture, when cold, is brittle, and of a granulated texture. The union of these two metals is remarkably slight. If a mixture of copper and lead is exposed to a fire no greater than that in which lead melts, the lead almost entirely runs off by itself; a separation of which no other example is known. What little lead is retained in the pores of the copper, may be scorified, and melted out, by a fire considerably less than is sufficient to fuse copper. If any of the copper is carried off by the lead, it swims unmelted on the surface.

Gold and silver are both dissolved by lead in a slight red heat. They are both rendered extremely brittle by the minutest quantity of this metal; though lead is rendered more ductile by a small quantity of either of them. In cupellation, a portion of lead is retained by gold, but silver parts with it all. On the other hand, in its eliquation from copper, if the copper contains any of the precious metals, the silver will totally melt out with the lead, but the gold will not. The attraction of lead to copper, however slight, is greater than that of copper to iron: a mixture of copper and iron being boiled in melted lead, the copper is imbibed by the lead, and the iron thrown up to the top. Silver is in like manner imbibed from iron by lead; whilst tin, on the contrary, is imbibed from lead by iron. If two mixtures, one of lead and tin, and another of iron and silver, be melted together, the result will be two new combinations, one of the tin with the iron at the top, the other with the lead and silver at the bottom: how carefully soever the matter be stirred and mixed in fusion, the two compounds, when grown cold, are found distinct, so as to be parted with a blow.

This metal is soluble in alkaline lixivia and expressed oils. Plates of lead boiled in alkaline lixivia, have a small part dissolved, and a considerable quantity corroded: the solution stains hair black. Lead, fused with fixed alkaline salts, is in part corroded into a dark-coloured scoria, which partially dissolves in water. Expressed oils dissolve the calces of lead, by boiling, in such large quantities as to become thick and consistent: hence plasters, cements for water-works, paint for preserving nets, &c. Acids have a greater affinity with leads than oils have. If the common plaster, composed of oil and litharge, be boiled in distilled vinegar, the litharge will be dissolved, and the oil thrown up to the top. The oil thus recovered, proves soluble like essential oils in spirit of wine; a phenomenon first taken notice of by Mr Geoffroy. 1216 Soluble in alkalies and in oils.

§ 6. *Tin.*

THE colour of this metal resembles silver, but is somewhat darker. It is softer, less elastic, and sonorous, than any other metal except lead. When bent backwards and forwards, it occasions a crackling sound, as if torn asunder. It is the lightest of all the malleable metals, being little more than seven times specifically heavier than water. The tenacity of its parts also is not very considerable; a tin wire of $\frac{1}{10}$ of an inch diameter being able to support only $49\frac{1}{4}$ pounds.

Tin is commonly reckoned the least ductile of all metals except lead; and certainly is so, in regard to ductility into wire, but not in regard to extensibility into leaves. These two properties seem not to be so much connected with one another as is generally imagined. Iron and steel may be drawn into very fine wire, but cannot be beat into leaves. Tin, on the other hand, may be beat into very thin leaves, but cannot be drawn into wire: gold and silver possess both properties in a very eminent degree; whilst lead, notwithstanding its flexibility and softness, cannot be drawn into fine wire, or beat into thin leaves. It melts the most easily of all the metals; about the 430th degree of Fahrenheit's thermometer. Heated till almost ready to melt, it becomes so brittle that large blocks may be easily beat to pieces by a blow. The purer sort, from its facility of breaking into long shining pieces, is called *grain-tin*. Melted, and nimbly agitated at the instant of its beginning to congeal, it is reduced into small grains or powder. 1217 Capable of being beat into thin leaves.

With the heat necessary for fusion, it may also be calcined; or at least so far deprived of its phlogiston as to appear in the form of a grey calx, which may be entirely reduced to tin by the addition of inflammable matter. The calcination of tin, like that of lead, begins by the melted metal losing its brightness, and contracting a pellicle on its surface. If the fire is raised to a cherry-red, the pellicle swells and bursts, discharging a small bright flame of an arsenical smell. By longer continuance in the fire, the metal is converted first into a greyish, and then into a perfectly white calx, called *putty*, which is used for polishing glass and other hard bodies. 1218 Calcined.

The calx of tin is the most refractory of all others. Even in the focus of a large burning mirror, it only softens a little, and forms crystalline filaments. With

glass

Tin.

glass of bismuth, and the simple and arsenicated glasses of lead, it forms opaque milky compounds. By this property it is fitted for making the basis of the imperfect glasses called *enamels*; (see GLASS and ENAMEL). The author of the Chemical Dictionary relates, "that having exposed very pure tin, singly, to a fire as strong as that of a glass-house furnace, during two hours, under a muffle, in an uncovered test, and having then examined it, the metal was found covered with an exceedingly white calx, which appeared to have formed a vegetation; under this matter was a reddish calx, and an hyacinthine glass; and lastly, at the bottom was a piece of tin unaltered. The experiment was several times repeated with the same success."

1219 Affinity of tin with arsenic.

Nitre deflagrates with tin, and hastens the calcination of this as well as of other imperfect metals. The vapours which rise from tin, by whatever method it is calcined, have generally an arsenical smell. Tin melted with arsenic falls in great part into a whitish calx: the part which remains uncalcined proves very brittle, appears of a white colour, and a sparkling plated texture, greatly resembling zinc. The arsenic is strongly retained by the tin, so as scarcely to be separable by any degree of fire; the tin always discovering, by its augmentation in weight, that it holds a portion of arsenic, though a very intense fire has been used. Hence, as the tin ores abound in arsenic, the common tin is found also to participate of that mineral.

1220 Arsenic separable from tin.

Henckel discovered a method of separating actual arsenic from tin; namely, by slowly dissolving the tin in eight times its quantity of an aqua-regia made with sal ammoniac, and setting the solution to evaporate in a gentle warmth: the arsenic begins to concrete whilst the liquor continues hot, and more plentifully on its growing cold, into white crystals. M. Margraaf, in the Berlin Memoirs for 1746, has given a more particular account of this process. He observes, that the white sediment which at first separates during the dissolution, is chiefly arsenical; that Malacca tin, which is accounted one of the purest sorts, yielded no less than $\frac{1}{8}$th its weight of arsenical crystals; that some sorts yielded more; but that tin extracted from a particular kind of ore, which contained no arsenic, afforded none. That the crystals were truly arsenical, and appeared from their being totally volatile; from their subliming (a little fixed alkaline salt being added to absorb the acid) into a colourless pellucid concrete; from the sublimate, laid on a heated copper-plate, exhaling in fumes of a garlic smell; from its staining the copper white: and from its forming, with sulphur, a compound similar to the yellow or sulphurated arsenic. He found that the arsenic was separable also by means of mercury; an amalgam of tin being long triturated with water, and the powder which was washed off committed to distillation, a little mercury came over, and bright arsenical flowers arose in the neck of the

1221 Dr Lewis's observation.

retort. Dr Lewis observes, that the crackling noise of tin in bending may possibly arise from its arsenic; as those operations which are said to separate arsenic from the metal, likewise deprive it of this property.

Tin may be allayed, in any proportion, with all metals by fusion: but it absolutely destroys their ductility, and renders them brittle, as in bell-metal; whence this metal has obtained the name of *diabolus metallorum*.

Mercury or quicksilver.

1222 Injurious to other metals.

Iron is dissolved by tin in a heat far less than that in which iron itself melts; the compound is white and brittle. Iron added to a mixture of lead and tin, takes up the tin, leaving the lead at the bottom; and in like manner, if lead, tin, and silver, are melted together, the addition of iron will absorb all the tin, and the tin only. Hence an easy method of purifying silver from tin.

1223 Not liable to rust.

Tin notwithstanding it is, like lead, soon deprived of its lustre by exposure to the air, is nevertheless much less liable to rust than either iron, copper, or lead; and hence is advantageously used for covering over the insides of other metalline vessels. The amalgam of mercury and tin is employed to cover one of the surfaces of looking-glasses; by which they are rendered capable of reflecting the rays of light. The amalgam also, mixed with sulphur and sal ammoniac, and set to sublime, yields a sparkling gold-coloured substance called *aurum mosaicum*; which is sometimes used as a pigment. This preparation is commonly made from quicksilver and tin, of each two parts, amalgamated together; and then thoroughly mixed with sulphur and sal ammoniac, of each one part and a half. The mercury and sulphur unite into a cinnabar, which sublimes along with the sal ammoniac; and, after sublimation, the aurum mosaicum remains at the bottom.

1224 Aurum mosaicum.

Sulphur may be united with tin by fusion; and forms with it a brittle mass, more difficultly fusible than pure tin. Sulphur has, in this respect, the same effect upon tin as upon lead. The allay of tin lessens the fusibility of these very fusible metals, while it increases the fusibility of other difficultly fusible metals, as iron and copper.

§ 7. *MERCURY or QUICKSILVER.*

MERCURY is a fluid metallic substance, of a bright silver colour, resembling lead or tin when melted; entirely void of taste and smell; extremely divisible; and congealable only in a degree of cold very difficultly produced, in this country, by art (see COLD and CONGELATION). It is the most ponderous of all fluids, and of all known bodies, gold and platina excepted; its specific gravity being to that of water nearly as 14 to 1. It is found to be specifically heavier in winter than in summer by 25 grains in 11 ounces

1225 Heavier in winter than in summer.

Neither air nor water, nor the united action of these two, seem to make any impression upon mercury: nor is it more susceptible of rust than the perfect metals. Its surface, nevertheless, is more quickly tarnished than gold or silver; because the dust which floats in the air, quickly seizes on its surface. The watery vapours also, which float in the air, seem to be attracted by mercury.

1226 Purification.

From these extraneous matters, which only slightly adhere to it, mercury may be easily cleansed by passing it through a clean new cloth, and afterwards heating it: but if mixed with any other metal, no separation can be effected without distillation. In this process, a small portion of some of the metals generally arises along with the mercury. Thus, quicksilver

Mercury or quick-ſilver.

ver diſtilled from lead, biſmuth, or tin, appears leſs bright than before; ſtains paper black; ſometimes exhibits a ſkin upon the ſurface; and does not run freely, or into round globules. Mr Boyle relates, that he has obſerved the weight of mercury ſenſibly increaſed by diſtillation from lead, and this when even a very moderate fire was made uſe of. By amalgamation with ſtellated regulus of antimony, and then being diſtilled after a few hours digeſtion, mercury is ſaid to

1227 Curious mercuries by Boyle.

become, by a few repetitions of the proceſs, more ponderous, and more active. The animated, or philoſophic mercuries of ſome of the alchemiſts, are ſuppoſed to have been mercury thus prepared. By the ſame, or ſimilar proceſſes, ſeem to have been obtained the curious mercuries which Boyle declared he was poſſeſſed of, and made himſelf; which were "conſiderably heavier in ſpecie than common quickſilver,—diſſolved gold more readily,—grew hot with gold, ſo as to be offenſive to the hand, and elevated gold in diſtillation." When quickſilver is to be diſtilled, it is proper to mingle it with a quantity of iron-filings; which have the property of making it much brighter than it can be otherwiſe obtained, probably by furniſhing phlogiſton.

By digeſtion in a ſtrong heat for ſeveral months, mercury undergoes a conſiderable alteration, changing into a powder, at firſt aſh-coloured, afterwards yel-

1228 Mercurius precipitatus per ſe.

low, at length of a bright red colour, and an acrid taſte; and is then called *mercurius precipitatus per ſe.* In this laſt ſtate it proves ſimilar to the red precipitate, prepared from a ſolution of mercury in nitrous acid. This calx proves leſs volatile in the fire than the mercury in its fluid ſtate. It ſupports for ſome time even a degree of red heat. In the focus of a burning mirror, it is ſaid to melt into glaſs when laid upon a piece of charcoal, and to revive into running mercury before it exhales. Evaporated by common fire, it leaves a ſmall portion of a light brown powder; which, Boerhaave relates, bore a blaſt-heat; ſwelled into a ſpongy maſs; formed with borax a vi-

1229 Mercury unalterable by a gentle heat;

treous friable ſubſtance; but vaniſhed in cupellation. By a long continued digeſtion in a gentle heat, mercury ſuffers little change. Boerhaave digeſted it in low degrees of heat, both in open and cloſe veſſels, for 15 years together, without obtaining any other reward for his labour than a ſmall quantity of black powder; which, by trituration, was quickly revived into running mercury. Conſtant triture, or agitation, produce a change ſimilar to this in a ſhort time. Both the black and red powders, by bare expoſure to a fire ſufficient to elevate them, return into fluid mercury. The red powder has been revived by ſimply grinding it in a glaſs mortar.

1230 Or by diſtillation.

In like manner, quickſilver remains unchanged by diſtillation. Boerhaave had the patience to diſtil 18 ounces of mercury upwards of 500 times over, without obſerving any other change than that its fluidity and ſpecific gravity were a little increaſed, and that

1231 Exploſion by the vapours of mercury.

ſome grains of a fixed matter remained. The vapours of mercury, like thoſe of all other volatile bodies, cauſe violent exploſions if confined. Mr Hellot gives an account of his being preſent at an experiment of this kind: a perſon pretending to fix mercury, had incloſed it in an iron box cloſely welded. When the mercury was heated, it burſt the box, and diſſipated in inviſible vapours.

Mercury or quick-ſilver.

Mercury diſſolves or unites with all metallic bodies, except three, *viz.* iron, arſenic, and nickel: in ſome 1232

caſes it will abſorb metals, particularly gold and ſilver, from their ſolutions in acids or alkalies; but does not act upon any metal when combined with ſulphur, nor on precipitates made by alkalies, nor on calces by fire. Whatever metal it is united with, it conſtantly preſerves its own white colour. It unites with any proportion of thoſe metallic ſubſtances with which it is capable of being combined; forming, with different quantities, amalgams of different degrees of conſiſtence. From the fluid ones, greateſt part of the quickſilver may be ſeparated by colature. Biſmuth is ſo far attenuated by mercury, as to paſs through leather with it in conſiderable quantity. It alſo promotes the action of quickſilver upon lead to a great degree; ſo that mercury united with $\frac{1}{4}$, $\frac{1}{8}$, or $\frac{1}{16}$ its weight of biſmuth, diſſolves maſſes of lead in a gentle warmth, without the agitation, triture, comminution, or melting heat neceſſary to unite pure mercury with lead. From theſe properties, this ſolution of biſmuth in mercury becomes a proper ſolvent for pieces of lead lodged in the human body.

Amalgamated with different ſubſtances.

1233 Separation of the amalgamated metals.

On triturating or digeſting amalgams for a length of time, a blackiſh or duſky coloured powder ariſes to the ſurface, and may be readily waſhed off by water. Some of the chemiſts have imagined, that the amalgamated metal was here reduced to its conſtituent parts: but pure mercury is by itſelf reducible to a powder of the ſame kind; and the metallic particles in this proceſs, united with the mercury, are found to be no other than the metal in its entire ſubſtance. Some metals ſeparate more difficultly than others; gold and ſilver the moſt ſo. Boerhaave relates, that if the powder which ſeparates from an amalgam of lead be committed to diſtillation with vinegar in a tall veſſel, the mercury will ariſe before the vinegar boils: that, by a like artifice, quickſilver may be made to diſtil in a leſs degree of heat than that of the human body: but Dr Lewis, though he made many trials, was never able to ſucceed.

1234 Becomes fixed by amalgamation with gold.

By amalgamation with gold, mercury may become exceedingly fixed; ſo as not to be diſſipable by the greateſt heat. Concerning this, Dr Brandt relates the following curious experiment: "Having amalgamated fine gold with a large proportion of quickſilver, and ſtrained off the ſuperfluous mercury, he digeſted the amalgam in a cloſe ſtopped veſſel for two months with ſuch a degree of heat, that a part of the quickſilver ſublimed into the neck of the glaſs. The matter being then ground with twice its weight of ſulphur, and urged with a gradual fire in a crucible, a ſpongy calx remained; which being melted with borax, and afterwards kept in fuſion by itſelf for half an hour, in a very violent fire, ſtill retained ſo much of the quickſilver as to become brittle under the hammer, and appear internally of a leaden colour. The metal being again amalgamated with freſh mercury, the amalgam again ground with ſulphur, and expoſed to an intenſe fire, a ſpongy calx remained as before. This calx being digeſted in two or three freſh parcels of aqua-regia, a ſmall portion of whitiſh matter remain-

ed

Mercury or quickſilver.

ed at laſt undiſſolved. The paper which covered the cylindrical glaſs wherein the digeſtion was performed, contracted, from the vapours, a deep-green circular ſpot in the middle, with a ſmaller one at the ſide; whereas the aqua-regia digeſted in the ſame manner by itſelf, or with gold, or with mercury, gave no ſtain. The firſt ſolution, on the addition of oil of tartar *per deliquium*, grew red as blood; on ſtanding, it depoſited, firſt, a little yellow calx, like aurum fulminans; afterwards, a bright matter like fine gold; and at laſt, a paler precipitate, inclining to green; its own deep red colour and tranſparency remaining unchanged. Being now committed to diſtillation, a colourleſs liquor aroſe; and the reſiduum, perfectly exſiccated, yielded, on edulcoration, a yellow calx of gold; which the alakaline lixivium had been unable to precipitate. The ſecond ſolution turned green on the admixture of the alkaline liquor, and let fall a white precipitate, which turned black and brown. The ſeveral precipitates were calcined with twice their weight of ſulphur, and then melted with four times their quantity of flint, and twelve of pot-aſh, in a fire vehemently excited by bellows. The ſcoria appeared of a golden colour, which, on pulverization and edulcoration, vaniſhed. At the bottom was a regulus, which looked bright like the pureſt gold; but was not perfectly malleable. Broken, it appeared internally white; and the white part amounted to at leaſt one-third its bulk Beſides this lump of metal, there were ſeveral others, white like ſilver, and ſoft as lead."

1235 Suppoſed to be convertible into water.

In Wilſon's chemiſtry, we have a proceſs for converting quickſilver into water, by dropping it by little and little into a tall iron veſſel, heated almoſt to a white heat in the bottom. Over the mouth of this veſſel were luted ſeven aludels; and on the top, a glaſs alembic head, with a beak, to which was fitted a receiver. The mercury was put in ſo ſlowly, that it required 16 hours for one pound. Every time that a little quantity of mercury was put in, it made a great noiſe, filling the aludel's head and receiver with white fumes. When the veſſels were cooled, a little water was found in each of the receivers, and in the firſt and ſecond ſome grains of crude mercury. The whole quantity amounted to 13 ounces and 6 drachms; which was expected to prove a powerful ſolvent of gold and ſilver: but, on trial, was found to be in no reſpect different from common water. On this experiment Dr Lewis has the following note.

1236 Dr Lewis's detection of the falſehood of this proceſs.

"The poſſibility of converting mercury into water, or at leaſt of obtaining a great quantity of water from mercury, has not only been believed by ſeveral great men in the chemical art, but ſome have even ventured to aſſert that they have actually made this change. Yet, neverthelеſs, they have delivered the hiſtory of this affair with ſuch marks, as ſeem to make the reality of the change extremely doubtful. Mr Boyle (in his tract *of the producibleneſs of Chemical Principles*, annexed to *Scept. Chemiſt.* p. 235.) ſays, "that he once obtained water from mercury without additament, without being able to make the like experiment ſucceed afterwards." M. Le Febure, who is generally looked upon as an honeſt practitioner, directs a proceſs ſimilar to that above (Wilſon's), for obtaining of this mercurial water. But it is to be ſuſpected, as Mr Hales very well obſerves (in his *Statical Experiments*, p. 200.), that Mr Boyle and others were deceived by ſome unheeded circumſtance, when they thought they obtained a water from mercury, which ſhould ſeem rather to have ariſen from the lute and earthen veſſels made uſe of in the diſtillation: for Mr Hales could not find the leaſt ſign of any moiſture upon diſtilling mercury in a retort made of an iron gun-barrel, with an intenſe degree of heat; although he frequently cohobated the mercury which came over into the recipient. "In a courſe of chemical experiments, I repeated Mr Hales's proceſs, and urged the mercury, which was let fall by little and little, through an aperture made in the gun-barrel, with a moſt intenſe degree of heat, without obtaining any water; but it being ſuſpected by a byſtander, that the mercury in this experiment came over before it had been ſufficiently acted upon by the fire, by reaſon of the lowneſs of the neck of the diſtilling inſtrument, the experiment was varied in the following manner. Sixteen ounces of mercury were heated in a crucible, in order to evaporate any moiſture that might have been accidentally mixed with it; and an iron gun-barrel of four feet in length, being placed perpendicularly in a good furnace, and a glaſs-head and recipient fitted to its upper part, the mercury was let fall by little and little into the barrel, and the fire urged with bellows. After each injection, the mercury made a conſiderable noiſe and ebullition, and aroſe into the head; where it ſoon condenſed and trickled down, in the common form of running mercury, into the recipient, without the leaſt perceptible appearance of any aqueous humidity." 1237

How to amalgate with regulus of antimony.

Mercury is difficultly amalgamated with regulus of antimony and copper; for which ſome particular manœuvres are required. Two of Dr Lewis's receipts for uniting quickſilver with copper, we have already given (n° 1153.): with regulus of antimony, mercury, he ſays, may be perfectly united, by pouring a ſmall ſtream of melted regulus into a conſiderable portion of mercury, made almoſt boiling hot. Another method directed by Henckel, is to put mercury into an iron mortar along with ſome water, and ſet the whole over the fire. When the water boils, a third or fourth part of melted regulus is to be poured in, and the maſs ground with a peſtle, till the amalgam is completed. The uſe of the water, as Dr Lewis obſerves, is to hinder the mercury from flying off by the heat of the regulus: but as the two are by this means not put together in ſo hot a ſtate, the union is more difficult, and leſs perfect. The loſs of the mercury, in the firſt proceſs, may be prevented by uſing a large veſſel, and covering it with a perforated iron-plate, through the hole in which the regulus is to be poured. This method is likewiſe applicable to the amalgamation of copper.

With ſulphur, mercury unites very readily, forming by trituration, or ſimple fuſion, a black powder or maſs, called *Ethiops mineral*; which, by careful ſublimation, becomes the beautiful red pigment called *vermillion*. (See SULPHUR, ſect. iv.). 1238

Preparations of mercurius dulcis in the moiſt way.

The extenſive uſe of mercurius dulcis in medicine has rendered it an object to chemiſts to find out ſome method of preparing it with leſs expence and trouble, and with more certainty of its effects, than it can be by the methods hitherto mentioned. This is now accompliſhed

Mercury of quick-silver. plished through the industry of Mr Scheele, to whom chemistry in general has been so much obliged. His method is as follows:

"Take half a pound of quicksilver, and as much pure common aquafortis. Pour it into a small cucurbit with a pretty long neck, stop the mouth with a little paper, and put it into warm sand. Some hours afterwards, when the acid appears no longer to act upon the quicksilver, the fire is to be augmented so as to make the solution nearly boil. This heat is to be continued for three or four hours, and the vessel now and then to be shaken. Towards the end, regulate the heat in such a manner that the solution shall gently boil for a quarter of an hour. In the mean time, dissolve 4½ ounces of pure common salt in six or eight pounds of water; pour this solution, still boiling, into a glass vessel, and immediately afterwards mix with it the abovementioned solution of quicksilver, which also must be boiling, in small quantities at a time, with constant agitation. When the precipitate has settled, decant off the clear liquor, and pour hot water again on the precipitate, with which it is to be edulcorated till the water standing upon it shall be entirely tasteless. Put the whole, obtained by these means, together, filter and dry it in a mild heat."

1239 How to obtain a perfectly saturated solution of quicksilver. On this process it is remarked, that when the quicksilver no longer effervesces with the acid, one would imagine that a saturation had taken place. But this is far from being the case. By increasing the heat the solution is still able to dissolve a great quantity; with this difference, however, that, whereas the quicksilver in the beginning is calcined, a great deal of it afterwards, in a metallic form, is dissolved, as appears from this, that not only no more elastic vapours ascend; but also, that with fixed and volatile caustic alkalies, a black precipitate is obtained; otherwise, when the solution contains only calcined quicksilver, the precipitate is yellow. If the black precipitate be gently distilled, quicksilver arises, and there remains a yellow powder, which is that part of the metal that was calcined by the nitrous acid. The fire must at any rate be augmented, in order to keep the mercurial calx dissolved, the compound of this metal and nitrous acid being extremely apt to crystallize even in the heat. There commonly remains some undissolved quicksilver; but it is always better to take too much than too little; for the more metal the mercurial solution contains, the more mercurius dulcis is obtained at last. The quantity here mentioned usually produces 8¼ ounces of mercurius dulcis. The mercurial solution must be cautiously poured into that of sea-salt, that no mercury may follow. Two ounces of salt would be sufficient for the precipitation of all the quicksilver; but when so small a quantity is used, it may easily happen, that some superabundant corrosive sublimate may adhere to the precipitate, which water alone is incapable of entirely separating. Among other advantages this method of making mercurius dulcis possesses, it is none of the least, that the powder is much finer than any to which it can be reduced in the common way by trituration, however long continued.

§ 8. *Zinc.*

This is a semimetal of a bluish white colour. It is the least brittle of any of the semimetals; and when amply supplied with phlogiston, which may be done by treating it in close vessels with inflammable matters, it possesses a semiductility, by which it may be flattened into thin plates. When broken, it appears formed of many flat shining plates or facets, which are larger when slowly than when hastily cooled. When heated, it is very brittle; and crackles like tin, only louder, when bent. Exposed to the air, it contracts in length of time a yellowish rust. Its specific gravity, according to Dr Lewis, is to that of water as $7\frac{1}{16}$ to 1. It begins to melt as soon as red-hot; but does not flow thin till the fire is raised to a white heat. Then the zinc immediately begins to burn with an exceedingly bright and beautiful flame. Kept just in fusion, it calcines slowly; not only on the upper surface, but likewise round the sides, and at the bottom of the crucible. If several pieces are just melted together, the mass, when grown cold, may be broken into the same number; their union being prevented by a yellowish calx, with which each piece is covered over. M. Malouin relates, in the French Memoirs for 1742, that a quantity of zinc being melted six times, and the fusion continued fifteen hours each time, it proved, on every repetition, harder, more brittle, less fusible, and less calcinable; that after the two first fusions, its colour was grey; after the third, brown; and after the fourth, black; that the fifth rendered it of a slate-blue; and the sixth of a clear violet.

Zinc.

1240 Deflagration.

1241 Flowers of zinc. So violent is the deflagration of zinc, that the whole of its calx is sublimed by it, in the form of light flocks of wool; which, however, are easily reduced to a fine powder. These are used in medicine, and reckoned an excellent remedy in epileptic cases. When once sublimed, they are by no means capable of being elevated again by the most violent heat. In a heat far greater than that in which they first arose, they suffer no alteration; in a very vehement one, they melt, according to Henckel, into a semiopaque green glass. Vitrified with borax, they give a grey, or brownish, glass. From the brightness of the flame of burning zinc, and the garlic smell which it is said to emit, some have concluded that zinc contained the phosphorine acid; which, from some other circumstances, is not altogether improbable.

1242 Dr Lewis's method of reducing them. The flowers of zinc have been thought very difficultly, or not at all, reducible to their metallic form by an addition of phlogiston. But Dr Lewis observes, that this difficulty proceeds not from their unfitness to be restored into the form of zinc, but from the volatility of the semimetal, which occasions its being dissipated in fumes, if the common methods are made use of. All calces, these of iron excepted, require a greater heat for their fusion than that in which the metal itself melts; and as a full melting heat is the greatest that zinc can sustain, it burns and calcines the instant of its revival, if the air is admitted; and in close vessels escapes, in part at least, through their pores. On mixing flowers of zinc with powdered charcoal, and urging them with a strong fire in a crucible, a deflagration and fresh sublimation ensue: sufficient marks that the zinc has been reduced to its metallic form; for as long as it remains in the state of calx, neither of these effects can happen. If the vessel is so contrived

trived

Zinc. trived as to exclude the air, and at the fame time to allow the reviving femimetal to run off from the vehemence of the heat, into a receiver kept cool, the zinc will there concrete, and be preferved in its metallic ftate. It is ftill more effectually detained by certain metallic bodies, as copper, or iron; with which the zinc, when thus applied, unites more readily and perfectly than it can be made to do by any other means.

1243 Oil from flowers of zinc by Mr Homberg. Homberg pretended to obtain an oil from the flowers of zinc, by diffolving them in diftilled vinegar, and then diftilling the folution in a glafs retort. At firft a quantity of phlegm arofe; then the fuperfluous acid; and at laft an empyreumatic oil. This laft, which Homberg imagined to proceed from the flowers of zinc, Newmann very juftly attributes to the diftilled vinegar.

1244 Another by Mr Hellot. An oil of another kind was obtained by Mr Hellot from the above folution, by digefting the afh-coloured refiduum, which remained after the diftillation, with the acidulous phlegm which came over, for eight or ten days; diftilling the tincture to drynefs; and repeating the extraction with the diftilled liquor, till the quantity of dry extract thus obtained was very confiderable. This refin-like matter, diftilled in a retort with a ftronger fire, yielded a yellowifh liquor, and a white fublimate. The liquor difcovered no mark of oil; but, upon being paffed upon the fublimate, immediately diffolved it, and then exhibited on the furface feveral drops of a reddifh oil. Some of this oil was taken up on the point of a pencil, and applied to gold and filver-leaf. In twenty-four hours the parts touched appeared, in both, equally diffolved.

1245 Zinc with other metals. Zinc does not unite in fufion with bifmuth, or the femimetal called *nickel*. It unites difficultly with iron; lefs fo with copper; eafier with the other metals. It renders iron or copper more eafily fufible; and, like itfelf, brittle whilft hot, though confiderably malleable when cold. It brightens the colour of iron

1246 Materials for fpecula. almoft into a filver hue, and changes that of copper into a yellow or gold colour. It greatly debafes the colour of gold; and renders near an hundredth part of that moft ductile metal brittle and untractable. A mixture of equal parts of each is very hard, white, and bears a fine polifh; hence it is propofed by Mr Hellot for making fpecula. It is not fubject to ruft or tarnifh in the air, like thofe metals whofe bafis is copper. It improves the colour and luftre of lead and tin, renders them firmer, and confequently fitter for feveral mechanic ufes. Tin, with a fmall proportion of zinc, forms a kind of pewter. Lead will bear an equal weight, without lofing too much of its malleability. Maoluin obferves, that arfenic, which whitens all other metals, renders zinc black and friable; that when the mixture is performed in clofe veffels, an agreeable aromatic odour is perceived on opening them; that zinc amalgamated with mercury, and afterwards recovered, proves whiter, harder and more brittle than before, and no longer crackles on being bent.

1247 Deflagration of zinc with other metals. Mixtures of zinc with other metals, expofed to a ftrong fire, boil and deflagrate more violently than zinc by itfelf. Some globules of the mixture are ufually thrown off during the ebullition, and fome part of the metal calcined and volatilized by the burning zinc:

hence this fubftance has been called *metallic nitre*. Gold itfelf does not entirely refift its action. It very difficultly volatilizes copper; and hence the fublimates obtained in the furnaces where brafs is made, or mixtures of copper and zinc melted, are rarely found to participate of that metal. On melting copper and zinc feparately, and then pouring them together, a violent detonation immediately enfues, and above half the mixture is thrown about in globules. 1248 Cannot be united with fulphur.

Zinc does not unite in the leaft with fulphur, or with crude antimony, which fcorify all other fubftances except gold and platina; nor with compofitions of fulphur and fixed alkaline falts, which diffolve gold itfelf. With nitre it deflagrates violently. Its flowers do not fenfibly deflagrate; yet alkalize double their weight of the falt more readily than the zinc itfelf. The alkaline mafs appears externally greenifh, internally of a purple colour. It communicates a fine purple to water, and a red to vinegar. The acetous tincture infpiffated, leaves a tenacious fubftance which foon runs in the air into a dark red cauftic liquor, the alkaheft of fome of the pretended adepts. 1249 Nitre alkalized by flowers of zinc.

§ 9. BISMUTH.

THIS femimetal, called, alfo *tin-glafs*, and by fome naturalifts *marcafita officinarum*, is fomewhat fimilar to the regulus of antimony. It appears to be compofed of cubes formed by the application of plates upon each other. Its colour is lefs white than that of regulus of antimony; and has a reddifh tinge, particularly when it is expofed to the air. In fpecific gravity it approaches to filver; being nearly ten times heavier than water. It has no degree of malleability; breaking under the hammer, and being reducible by trituration to fine powder. It melts a little later than tin, and feems to flow the thinneft of all metallic fubftances. Bifmuth is femivolatile, like all other femimetals. When expofed to the fire, flowers rife from it; it is calcined; and converted into a litharge and glafs nearly as lead is; (See GLASS). It may even be employed, like that metal, in the purification of gold and filver by cupellation. (See REFINING). When in fufion, it occupies lefs volume than in its folid ftate: a property peculiar to iron among the metals, and bifmuth among the femimetals. It emits fumes in the fire as long as it preferves its metallic form; when calcined or vitrified, it proves perfectly fixed. 1250 Convertible into litharge and glafs.

Bifmuth mingles in fufion with all the metalline fubftances, except regulus of cobalt and zinc. The addition of nickel or regulus of antimony, renders it mifcible with the former, though not with the latter. It greatly promotes the tenuity as well as facility of the fufion of all thofe metals with which it unites. It whitens copper and gold, and improves the colour of fome of the white metals: mixed in confiderable quantity; it renders them all brittle, and of a flaky ftructure like its own. If mixed with gold or filver, a heat that is but juft fufficient to melt the mixture, will prefently vitrify a part of the bifmuth; which, having then no action on thofe perfect metals, feparates, and glazes the crucible all round. 1251 Promotes the fufion of all the metals.

Regulus of antimony.

§ 10. *Regulus of Antimony.*

1252 Appearance of a ſtar on its ſurface. This ſemimetal, when pure, and well fuſed, is of a white ſhining colour, and conſiſts of laminæ applied to each other. When it has been well melted, and not too haſtily cooled, and its ſurface is not touched by any hard body during the cooling, it exhibits the perfect figure of a ſtar, conſiſting of many radii iſſuing from a centre. This proceeds from the diſpoſition that the parts of this ſemimetal have to arrange themſelves in a regular manner, and is ſimilar to the cryſtallization of ſalts.

Regulus of antimony is moderately hard; but, like other ſemimetals, it has no ductility, and breaks in ſmall pieces under a hammer. It loſes ⅐ of its weight in water. The action of air and water deſtroys its luſtre, but does not ruſt it ſo effectually as iron or copper. It is fuſible with a heat ſufficient to make it red

1253 Sublimable. hot; but when heated to a certain degree, it fumes continually, and is diſſipated in vapours. Theſe fumes form what are called the *argentine flowers* of regulus of antimony, and are nothing but the earth of this ſemimetal deprived of part of its inflammable principle, and capable of being reduced to its reguline ſtate by an union with this principle.

1254 Separation of the ſulphur from antimony. There are different methods of preparing the regulus of antimony; but all of them conſiſt merely in ſeparating the ſulphur which this mineral contains, and which is united with the regulus. It is plain, therefore, that regulus of antimony may be made by an addition of any ſubſtance to crude antimony in fuſion, which has a greater attraction for ſulphur than the regulus itſelf has. For this purpoſe, alkaline ſalts have been employed, either previouſly prepared, or extemporaneouſly produced in the proceſs, by a deflagration of tartar and nitre. By this means, the ſulphur was indeed abſorbed; but the hepar ſulphuris, formed by the union of the ſulphur and alkali, immediately diſſolved the regulus, ſo that very little, ſometimes none at all, was to be obtained diſtinct from the ſcoria. Metals are found to anſwer better than alkaline ſalts, but the regulus is ſeldom or never free from a mixture of the metal employed. The way of obtaining a very pure regulus, and in great quantity, is to calcine the antimony in order to diſſipate its ſulphur; then to mix the calx with inflammable matters, ſuch as oil, ſoft ſoap, &c. which are capable of reſtoring the principle of inflammability to it. This method was invented by Kunckel. Another, but more expenſive way of procuring a large yield of very pure regulus, is, by digeſting antimony in aqua-regis, which diſſolves the reguline part, leaving the ſulphur untouched, precipitating the ſolution, and afterwards reviving the precipitate by melting it with inflammable matters.

1255 Regulus eaſily miſcible with mercury. There are conſiderable differences obſerved in the regulus of antimony, according to the different ſubſtances made uſe of to abſorb the ſulphur. When prepared by the common methods, it is found to be very difficultly amalgamated with mercury; but Mr Pott has diſcovered, that a regulus prepared with two or five parts of iron, four of antimony, and one of chalk, readily unites with mercury into an hard amalgam, by bare trituration with water. Marble and quicklime ſucceed equally well with chalk; but clay, gypſum, or other earths, have no effect.

1256 Extemporaneous regulus with cawk. One earthy ſubſtance, found in lead-mines, and commonly called *cawk*, has a very remarkable effect upon antimony. This is found in whitiſh, moderately compact and ponderous maſſes; it is commonly ſuppoſed a ſpar; but differs from bodies of this kind, in not being acted upon by acids, (ſee n° 1068). If a lump of cawk, of an ounce or two, be thrown red hot into 16 ounces of melted antimony, the fuſion continued about two minutes, and the fluid matter poured off, "you will have 15 ounces like poliſhed ſteel, and as the moſt refined quickſilver." *Phil. Tranſ.* n° 110. Dr Lewis mentions his having repeated this experiment ſeveral times with ſucceſs: but having once varied it by mixing the cawk and antimony together at the firſt, a part of the antimony was converted into a very dark black vitreous matter, and part ſeemed to have ſuffered little change; on the ſurface of the maſs ſome yellow flowers appeared.

Regulus of antimony enters into the compoſitions for metallic ſpeculums for teleſcopes, and for printing-types. It is alſo the baſis of a number of medicinal preparations; but many of theſe, which were formerly much eſteemed, are found to be either inert, uncertain, or dangerous in their operations. When taken in ſubſtance, it is emetic and purgative, but uncertain in its operation; becauſe it only acts in proportion to the quantity of ſolvent matter it meets with in the ſtomach; and if it meets with nothing capable of acting upon it there, the regulus will be quite inactive. For theſe reaſons, the only two preparations of antimony now retained, at leaſt by ſkilful practitioners, are the infuſion of glaſs of antimony in wine and emetic tar-

1257 Glaſs of antimony. tar. For making the glaſs of antimony we have the following proceſs. "Take a pound of antimony; reduce it to fine powder, and ſet it over a gentle fire; calcine it in an unglazed earthen pan, till it comes to be of an aſh colour, and ceaſes to fume: you muſt keep it continually ſtirring; and if it ſhould run into lumps, you muſt powder them again, and then proceed to finiſh the calcination. When that is done, put the calcined antimony into a crucible; ſet it upon a tile in a wind-furnace; put a thin tile on the top; and cover it all over with coals. When it is brought into fuſion, keep it ſo in a ſtrong fire for an hour: then put into it an iron rod; and when the melted antimony, which adheres to it, is tranſparent, pour it upon a ſmooth, hot, marble; and when it is cold, put it up for uſe. This is *vitrum antimonii*, or *ſtibium*."

This preparation is more violent in its effects than the pure regulus itſelf; becauſe it contains leſs phlogiſton, conſequently is ſimilar to a regulus partially calcined, and ſo more ſoluble. Hence it is the moſt proper for infuſion in wine, or for making the tartar emetic. It is obviouſly, however, liable to great uncertainties in point of ſtrength; for as the antimony is more or leſs ſtrongly calcined, the glaſs will turn out ſtronger or weaker in its operation, and conſequently all the preparations of it muſt be liable to much uncer-

1258 Difference of ſtrength in emetic tartars. tainty. This uncertainty is very apparent in the ſtrength of different parcels of emetic tartar: accordingly Mr Geoffroy found by examination of different emetic tartars, that an ounce of the weakeſt contain-

ed

Rugulus of antimony. ed from 30 to 90 grains of regulus; an ounce of moderate ftrength contained about 108 grains; and an ounce of the ftrongeft kind contained 154 grains. For thefe reafons, the author of the Chemical Dictionary recommends the pulvis algaroth as the moft proper material for making emetic tartar; being per-

1259 Pulvis algaroth the moft proper material for emetic tartar. fectly foluble, and always of an equal degree of ftrength. Emetic tartar, as he juftly obferves, ought to be a metallic falt compofed of cream of tartar faturated with the regulus of antimony; and M. Beaumé has fhown fuch a faturation to be poffible, and that the neutral falt cryftallizes in the form of pyramids. They are tranfparent while moift; but by expofure to a dry air, they lofe the water of their cryftallization and become opaque. The preparation of this falt, according to M. Baumé, confifts in mixing together equal parts of cream of tartar, and levigated glafs of antimony: thefe are to be thrown gradually into boiling water; and the boiling continued till there is no longer any effervefcence, and the acid is entirely faturated. The liquor is to be filtered; and upon the filter is obferved a certain quantity of fulphureous matter along with fome undiffolved parts of the glafs of antimony. When the filtered liquor is cooled, fine cryftals will be formed in it, which are a foluble tartar perfectly faturated with glafs of antimony. He obferves, that the diffolution is foon over if the glafs is well levigated, but requires a long time if it is only grofsly pounded.

1260 Objection to its ufe. The trouble of levigating glafs of antimony, as well as the uncertainty of diffolving it, would render *pulvis algaroth* much preferable, were it not on account of its price; which would be a temptation to thofe

1261 Scheele's theory of the nature of pulvis algaroth. in ufe to prepare medicines, to fubftitute a cheaper antimonial preparation in its place. This objection, however, is now in a great meafure removed by Mr Scheele; who demonftrated that the pulvis algaroth is no other than regulus of antimony half calcined by the dephlogifticated marine acid in the corrofive fublimate made ufe of for preparing the antimonial cauftic. If therefore we can fall upon any other method of dephlogifticating the regulus, we fhall then be able to combine the marine acid with it; and by feparating them afterwards, may have the powder of algaroth as good as from the butter of antimony itfelf. One of the methods of dephlogifticating the regulus is by nitre. Our author therefore gives the following receipt for the powder in queftion.

1262 His receipt for making it cheap. "Take of powdered crude antimony one pound; powdered nitre, one pound and a half; which, after being well dried and mixed, are to be detonated in an iron mortar. The hepar obtained in this manner is to be powdered, and a pound of it to be put into a glafs veffel, on which firft a mixture of three pounds of water and 15 ounces of vitriolic acid is to be poured, and afterwards 15 ounces of powdered common falt are to be added; the glafs veffel is then to be put in a fand-bath, and kept in digeftion for 12 hours, during which period the mafs is to be conftantly ftirred. The folution, when cool, is to be ftrained through linen. On the refiduum one third of the above menftruum is to be poured, and the mixture digefted and ftrained. From this folution, when it is diluted with boiling water, the pulvis algarothi precipitates, which is to be well edulcorated and dried."

As regulus of antimony, like other metallic fubftances, is foluble in liver of fulphur, it happens, that, on boiling antimony in an alkaline ley, the falt, uniting with the fulphur contained in that mineral, forms an hepar fulphuris, which diffolves fome of the reguline part. If the liquor is filtered, and faturated with an acid, the regulus and fulphur will fall together in form of a yellowifh or reddifh powder, called *golden fulphur of antimony*. If the ley is fuffered to cool, a like precipitation of a red powder happens. This laft is called *kermes mineral*. Arfenic. 1263 Golden fulphur of antimony and kermes mineral.

Nitre deflagrates violently with antimony, confuming not only its fulphureous part, but alfo the phlogifton of the regulus: and thus reduces the whole to an inert calx, called *antimonium diaphoreticum*. If equal parts of nitre and antimony are deflagrated together, the fulphureous part is confumed, as well as part of the inflammable principle of the regulus. The metalline part melts, and forms a femivitreous mafs of reddifh colour, called *crocus metallorum*, or *liver of antimony*. It is a violent emetic, and was formerly ufed for making infufions in wine fimilar to thofe of glafs of antimony; but is now difufed on account of its uncertainty in ftrength. It is ftill ufed by the farriers: but the fubftance fold for it is prepared with a far lefs proportion of nitre; and fometimes even without any alkaline falt being added to abforb part of the antimonial fulphur. This crocus is of a dull red colour; and, when powdered, affumes a dark purple. 1263 Diaphoretic antimony. 1265 Crocus metallorum.

§ II. *Arsenic.*

This fubftance, in its natural ftate, has no appearance of a metal, but much more refembles a falt, which, as has been already obferved, it really is when deprived of its phlogifton. When united to a certain quantity of phlogifton, it affumes a metallic appearance; and in this ftate it is found, as Mr Bergman informs us, in Bohemia, Hungary, Saxony, Hercynia, and other parts; particularly at Alfatia in the mines called *St Marieux*. The maffes in which it is found are frequently fhapelefs, friable, and powdery; but fometimes compact, and divided into thick convex lamellæ, with a needle-formed or micaceous furface: it takes a polifh, but foon lofes it again in the air. When frefh broken, it appears compofed of fmall needle-like grains of a leaden colour, foon becoming yellow, and by degrees blackifh; exceeding copper in hardnefs, though as brittle as antimony. 1266 Arfenic found naturally in a metallic form.

Reguline arfenic, whether found naturally or prepared by art, very readily parts with as much of its phlogifton as is fufficient to make it fly off in a white fmoke; but this ftill retains a very confiderable quantity of phlogiftic matter, as is evident from its producing nitrous air by the affufion of nitrous acid, and from the experiments already related of the preparation of the acid of arfenic. This calx indeed is the form in which arfenic is moft commonly met with. It is lefs volatile than the regulus; and by fublimation in a glafs veffel affumes an opaque cryftalline appearance from becoming white on the furface; but that which cryftallizes in the bowels of the earth does not appear to be fubject to any fuch change. 1267 Regulus of arfenic eafily converted into the common white kind.

White arfenic, though a true metalline calx, may be mixed in fufion with the fame metals which will unite with the regulus. This feems contrary to the general rule of other calces, which cannot be united with any metal 1268 White arfenic may be mixed with other metals.

Arſenic.

metal in its metalline ſtate; but it muſt be remembered, that by this operation the arſenical calx is reduced to a regulus by the phlogiſton of the metal: whence, in all fuſions of this kind, ſome ſcoriæ riſe to the top, conſiſting of the calcined metal and part of the white arſenic.

1269
Solution of arſenic in water.

Eight parts of diſtilled water diſſolve, by means of moderate heat, one part of calcined arſenic, and by boiling may be made to take up 15. The ſolution changes ſyrup of violet green, but the tincture of turnſole red. It is not changed by neutral ſalts, but ſlowly precipitates the ſolutions of metals, the arſenic united to the metallic calx falling to the bottom.—"It may be aſked (ſays Mr Bergman), whether the whole of the arſenic, or only the arſenical acid, unites with the metallic calx, yielding the phlogiſton to the menſtruum of the other metal?" Certainly ſuch a mutual commutation of principles does not appear improbable, if we conſider only thoſe caſes in which the menſtruum is vitriolic or nitrous acid: but as iron, for example, united with marine acid (which does not attract the phlogiſton of white arſenic), as well as when it is joined to the nitrous acid, is precipitated, it would appear that the whole of the arſenic is united, at leaſt in certain caſes, to the metallic calces.

1270
And in ſpirit of wine.

One part of arſenic is diſſolved by 70 or 80 of boiling ſpirit of wine.

1271
In vitriolic acid.

Arſenic diſſolves partially in concentrated vitriolic acid, but concretes in the form of cryſtalline grains on cooling. Theſe diſſolve in water with much greater difficulty than the arſenic itſelf. On the blow-pipe they emit a white ſmoke, but form into a globule by fuſion, which at firſt bubbles, but ſoon grows quiet, and is but ſlowly conſumed even in a white heat. This fixity is occaſioned by the acid carrying off the phlogiſton of the arſenic, and thus leaving a greater proportion of its peculiar acid than what it naturally contains; and therefore the more frequently the operation is repeated, the more fixed the arſenic becomes, though it is ſcarce poſſible to diſſipate the arſenical phlogiſton as perfectly with this acid as with the nitrous; the effects of which have been already particularly mentioned.

1272
In marine acid.

The marine acid, which naturally contains phlogiſton, diſſolves about one-third of its weight of arſenic, a great part of which ſeparates ſpontaneouſly on cooling in a ſtate of ſaturation with the acid. This ſalt, which may be had in a cryſtalline form, is much more volatile than the former, readily ſubliming in a cloſe veſſel with a moderate heat; but is ſoluble with difficulty in boiling water. It is of a fine yellow colour, and ſcarcely differs from butter of arſenic, except in its degree of concentration. The nature of marine acid prevents it from diſengaging the arſenical acid from the phlogiſton of the ſemimetal, as will eaſily appear from what has been ſaid concerning that acid. The arſenical acid, however, is eaſily made to appear by the addition of that of nitre, as will be underſtood from the directions given by Mr Scheele for the preparation of the acid of arſenic.

1273
Phlogiſticated alkali cannot precipitate arſenic except from marine acid.

Arſenic is not precipitated from its ſolution in vitriolic and nitrous acids by the phlogiſticated alkali, which yet very readily precipitates all other metals. From the marine acid, however, it is precipitated by its means of a white colour; but unleſs the ſolution be very acid, the addition of mere water will throw down a precipitate of the ſame colour.

1274
Decompoſed by dephlogiſticated marine acid.

Dephlogiſticated marine acid deprives arſenic of its inflammable principle; ſo that in the diſtilling veſſel we find water, acid of arſenic, and marine acid, regenerated.

1275
Phenomena with other acids.

Arſenic is diſſolved by its own acid, and forms cryſtalline grains with it as well as with that of fluor and borax. Saccharine acid diſſolves it likewiſe, and forms priſmatic cryſtals; and a ſimilar ſalt is alſo formed by the acid of tartar. Vinegar, and the acids of vinegar and phoſphorus, form with it cryſtalline grains, which are ſcarcely ſoluble in water.

1276
Liver of arſenic.

Solutions of fixed alkali diſſolve arſenic; and, when loaded with it, form a brown tenacious maſs, called *liver of arſenic*. The arſenic is partly precipitated by mineral acids, though part of it gradually loſes its phlogiſton, and adheres more tenaciouſly. Solution made with volatile alkali ſeems to effect this decompoſition more readily, as no precipitation is made by acids. Limpid ſolution of ſaline hepar, dropped into a ſolution of white arſenic, floats upon the ſurface in form of a grey ſtratum, which at length diſturbs the whole liquor.

1277
Effects on metals.

By the aſſiſtance of heat ſolutions of arſenic attack ſome of the metals, particularly copper, iron, and zinc; the ſolutions of the two laſt yielding cryſtals by evaporation. No alteration is made on theſe compounds by alkaline ſalts or by acids: volatile alkali does not diſcover the copper by changing the colour of the ſolution blue; nor does the phlogiſticated alkali throw down any blue precipitate from the ſolution of iron. The reaſon of this is the ſuperabundance of phlogiſton in the ſolutions; for the arſenical acid takes up all metals: when united with copper, it ſhows a blue colour with volatile alkali; and when united with iron, it lets fall a Pruſſian blue in the uſual way; but the quantity of phlogiſton which converts the acid into white arſenic, prevents the appearance of theſe phenomena when the latter is made uſe of.

1278
Unites eaſily with ſulphur.

Arſenic, either in its calcined or reguline ſtate, may be united with ſulphur; in which caſe it appears either of a red or yellow colour, according to the quantity of ſulphur with which it is united. Theſe compounds are ſpontaneouſly produced by nature; both of them ſometimes pellucid and cryſtalline; with this difference, however, that the yellow ſeems to affect a lamellated, and the red a cryſtalline, form.

1279
Realgar and orpiment.

Theſe are called *red and yellow orpiment*, or realgar and orpiment; the ſpecific gravity of realgar being about 3.225; of orpiment, 5.315. Both of theſe ſublime totally with a moderate heat, unleſs when they happen to be mixed with other ſubſtances. They readily unite with thoſe metals which form an union with the arſenic and ſulphur of which they are compoſed. Silver mineralized by fuſion with orpiment, forms a ſubſtance ſimilar to what is called the red ore of that metal. Iron, in conjunction with orpiment, aſſumes a white, poliſhed, and metallic appearance, ſimilar to that of the white or arſenical pyrites; and by various combinations of theſe ſubſtances with metals of different kinds, many of the natural metalline ores may be produced.

1280
Phenomena with nitrous acid.

Nitre, when treated with mineralized arſenic, detonates

Arsenic.

tonates partly with the sulphur, and partly with the phlogiston of the arsenic; the alkaline basis of the salt either forming sal polychrest with the acid of the sulphur, or uniting with the alkali, and forming the neutral arsenical salt. By the addition of fixed alkali in proper quantity, either to orpiment or realgar, and then exposing the mixture to a subliming heat, nitre retains the sulphur, but lets go the greatest part of the arsenic; the hepatic mass, however, retains a small quantity of the latter; and if there is much alkali, scarce any of the arsenic arises.

1281 Butter of arsenic.

On distilling orpiment with twice or thrice it quantity of corrosive sublimate, two liquids arise which refuse to unite; and at length, on augmenting the heat, a cinnabar arises. A butter of arsenic is found at the bottom of the receiver, of a ferruginous brown colour, but pellucid: in the open air it first sends forth a copious fume of a white colour, and then gradually attracts the moisture of the atmosphere, by which it is

1282 Can scarce be made to unite with marine acid.

precipitated. It is remarkable that it unites so slowly with marine acid, that they seem to repel one another; nor can they be made to unite beyond a certain degree. By the affusion of distilled water, a white powder will be precipitated, which, though ever so well washed, retains some acidity; for a portion of butter of antimony is produced by distillation, as is likewise true of the pulvis algaroth. The smoke has a peculiar penetrating smell, somewhat similar to that of phlogisticated vitriolic acid, and lets fall white flow-

1283 Oil of arsenic.

ers. The liquor which swims above, and which, by chemical authors, has been compared to oil, is yellowish and pellucid, separating a white arsenical powder by the addition of water and spirit of wine. It is not affected by the stronger acids; but effervesces, and lets fall a precipitate, with alkalies. On keeping it with a cucurbit with a long neck unstopped, white flowers gradually concrete round the orifice, which are lax, and sometimes approaching to a crystalline form. And lastly, by spontaneous evaporation, pellucid crystals appear at the bottom of the liquor, which are soluble in water with great difficulty; but when dissolved, precipitate silver from nitrous acid, and let fall some arsenic on the addition of an alkali. When put into lime-water, a cloud slowly surrounds them: on being exposed to the fire, they totally sublime without any arsenical smell, without decrepitation, or losing their transparency; but if ignited phlogistic matter comes in contact with them, the arsenical smell instantly appears. No traces of mercury are to be found in this liquor by treating it either with alkali or copper; nor the slightest precipitation is made by it on being dropped into a solution of terra ponderosa in the marine acid: from all which it appears, that this liquor is only a very dilute butter of arsenic, containing less of the mercury on account of the quantity of water it has. The butter contains the acid in its most concentrated state, and is therefore loaded with a larger quantity of arsenic: the former liquor will therefore be obtained in much larger quantity, by setting the mixture of corrosive sublimate and arsenic to stand a night in a cellar, or moistened with water, before it be subjected to distillation. As the common marine acid can dissolve only a determined quantity of the butter, it naturally follows, that what remains after complete saturation should totally refuse to mix. The acid, however, when too much diluted, precipitates the butter; but in proportion to its strength it dissolves a greater quantity.

Arsenic.

1284 Arsenic mineralized by sulphur.

Arsenic mineralized by sulphur is not dissolved by water, but is affected by the different acids, according to the particular circumstances of each. Nitrous acid and aqua-regia act most powerfully; the former soon destroys the red colour of the realgar, and converts it into yellow orpiment; its primary action being to calcine the arsenic, without affecting the yellowness of the sulphur. It makes no change on the colour of orpiment. Aqua-regia, by long digestion, takes up the arsenic, and leaves the sulphur at the bottom; and hence we may find out the proportions of the two ingredients. Some dexterity, however, is necessary in performing this operation with accuracy; for if, on the one hand, the menstruum be too weak, part of the arsenic will remain undissolved; and if, on the other, it be too strong, part of the sulphur will be decomposed; for strong nitrous acid is capable of decomposing sulphur by long digestion, having a greater attraction for phlogiston than the vitriolic acid itself. The colour of the residuum ought to be grey; for as long as any yellow particles remain, it is a sign that some of the arsenic also remains. If any iron be present in the compound, it is all dissolved, by reason of the superior attraction of the acid for it, before any of the arsenic is taken up, unless it shall have been calcined either by the access of air and heat employed in the operation, or by the too great power of the menstruum.

1285 Pure regulus of arsenic, how prepared.

The pure regulus of arsenic may be obtained artificially from white arsenic, either by sublimation with oil, black flux, or other phlogistic materials; or by melting it with double its weight of soap and potashes; or lastly, by precipitation by means of some other metal, from orpiment or sandarack melted with sulphur and fixed alkali. By the first of these methods it is obtained in a crystalline form, octohedral, pyramidal, or even prismatic. Mr Bergman mentions a natural

1286 Mispickel, a natural regulus of arsenic.

regulus of arsenic, named *mispickel*, which along with some sulphur contains a large quantity of iron united with the regulus into a metallic compound; but tho' the iron sometimes amounts to $\frac{1}{4}$ or even $\frac{1}{3}$ of the whole, it nevertheless remains untouched by the magnet. When ignited, it sends forth an arsenical smell, and soon becomes obedient to the magnet, even though the operation be performed on a tile without any additional phlogiston; it melts easily in an open fire, and in close vessels the greater part of the regulus sublimes, leaving the iron at the bottom.

1287 Great volatility of this semimetal.

The pure regulus of arsenic is vastly more volatile than any other metal, and therefore cannot be melted. It begins to send forth a visible smoke in 180° of the Swedish thermometer, and is capable of inflammation; but in order to inflame it, it must be thrown into a vessel previously heated to a sufficient degree, otherwise it will be sublimed. The flame is of an obscure whitish blue, diffusing a white smoke and garlic smell. In close vessels it retains its metallic form, and may be sublimed of any figure we please.

1288 Effects of regulus of arsenic on other metals.

Regulus of arsenic unites with many of the metals, but destroys the malleability of those with which it enters into fusion. It renders those more easy of fusion which are melted with difficulty by themselves; but tin, the most easily fusible of all the metals, be-

comes

Arsenic.

comes more refractory by being united with arsenic. This metal acquires a permanent and shining whiteness by its union with regulus of arsenic, and is able to retain half its own weight of the arsenical metal. The other white metals become grey by fusion with this semimetal, platina only excepted. Gold fused in a close vessel with regulus of arsenic, scarcely takes up $\frac{1}{10}$ of its weight; silver $\frac{1}{4}$; lead $\frac{1}{6}$; copper $\frac{1}{6}$; and iron more than its own weight. The magnetic property of this last metal is destroyed by a large quantity of regulus, though the exact proportion which destroys it can scarcely be determined, as some of the iron is always taken up by the scoria; but according to Mr Bergman, less than an equal quantity is certainly sufficient. Bismuth retains $\frac{1}{15}$ of its weight; zinc $\frac{1}{5}$; regulus of antimony $\frac{1}{8}$; and manganese an equal quantity. Nickel and regulus of cobalt take up a large quantity; but how much cannot be determined, as it is next to impossible to procure any of those metals in a state of perfect purity. In a sufficient degree of heat, and by a triture of several hours, regulus of arsenic takes up about $\frac{1}{6}$ of its own weight of mercury, forming an amalgam of a grey colour.

1289 May be expelled by heat from all the metals with which it is united.

Regulus of arsenic, by reason of its volatility, may be expelled from all the metals with which it is united; but, in flying off, it generally carries along with it some of the metals with which it is united, gold and silver not excepted, if the degree of heat be great and very suddenly applied. Platina, however, perfectly resists the volatilization; and by reason of its refractory nature, even retains a portion of the arsenic.

1290 Effects of it upon alkaline salts and nitre.

This semimetal cannot be united by fusion with alkaline salts until the phlogiston is considerably diminished, and the regulus approaches to the nature of pure arsenical acid. By adding regulus therefore to nitre in fusion, a detonation ensues, the phlogiston of the former is totally destroyed, and the acid uniting with the alkali of the nitre forms a neutral arsenical salt, similar to that made with white arsenic and nitre. By distillation with dry acid of arsenic, the regulus sublimes before it can be acted upon by the acid; but when thrown into the acid in fusion, soon takes fire, and sends forth a white smoke: for the acid, being in this instance deprived of its phlogiston, separates that principle from the regulus, and unites with it in such quantity as to regenerate white arsenic; while on the other hand, the regulus, by this operation, is so far deprived of its phlogiston as to appear in the form of a calx.

1291 Decomposes corrosive sublimate.

By distillation with corrosive sublimate, a smoking butter, and small quantity of mercurius dulcis and running mercury, are procured; which happens in consequence of a double elective attraction; the regulus of arsenic yielding its phlogiston to the base of the corrosive sublimate, which being thus really calcined, reduces the former to perfect mercury, while the marine acid takes up the calx of arsenic. The regulus of arsenic readily unites with sulphur, and forms the same red and yellow compounds that have already been mentioned when speaking of white arsenic; it is soluble in hepar sulphuris, but may be precipitated by every other metal which can unite with the hepar.

1292 Converted into white arsenic by the vitriolic acid.

Regulus of arsenic is not affected by the vitriolic acid, unless when concentrated and assisted by heat. The inflammable part of the regulus which phlogisticates the acid flies off, so that the remainder assumes the nature of white arsenic, and exhibits the same properties with menstrua as any other metallic calx: the same holds good with nitrous acid, except that it attracts the phlogiston more vehemently. Marine acid has little or no effect except when boiling.

1293 Effects of it on metallic solution.

Regulus of arsenic precipitates certain metals dissolved in acids, such as gold and platina, dissolved in aqua-regia, as well as silver and mercury in vitriolic and nitrous acids. Silver generally appears in beautiful polished spiculæ, like the arbor Dianæ; but if the arsenic be suffered to stand long in the nitrous solution but little diluted, the silver spiculæ are again dissolved, the arsenic in the mean time being dephlogisticated. Solutions of bismuth and antimony are scarcely rendered turbid. Iron may be separated from regulus of arsenic by digestion with marine acid, or with aqua-regia; neither of which will touch the arsenic, as long as any iron remains; but in order to succeed in this operation, subtile pulverisation is necessary as well as a just quantity and strength of the menstruum. Heat must also be carefully avoided. The regulus is also dissolved by hepar sulphuris and by fat oils, the latter forming with it a black mass like plaster.

§ 12. *Cobalt.*

Cobalt.

Regulus of cobalt, or more properly pure cobalt itself (what we have under the name of *cobalt* being only a calx of the regulus), is a semimetal of a reddish white colour, close-grained, so as to be easily reducible to powder, about 7.7 of specific gravity, and forming itself into masses of a needle-like texture, placed upon one another. It is seldom or never found native, but almost always calcined and united with arsenic, the arsenical acid, sulphur, iron, &c.

1294 Zaffre, a calx of cobalt.

The zaffre used in commerce is an impure and grey calx of cobalt. When mixed with three times its weight of pulverised flints, and exposed to a strong fire, it melts into glass of a dark blue colour, called *smalt*, used in tinging other glasses, and in painting.

1295 Smalt, how produced.

With three times its weight of black flux, a small quantity of tallow and marine salt, it affords the semimetal known by the improper name of *regulus of cobalt*; but the reduction is very difficult.

1296 Regulus of cobalt difficult to reduce.

For this purpose a large quantity of flux must be made use of, and the crucible kept a considerable time in a white-red heat, that the matter may become very fluid, and that the scoria may be completely fused into a blue glass, at which period the cobalt sinks in the form of a button to the bottom.

1297 Properties of cobalt when exposed to heat.

Cobalt melts in a strong red heat, is very fixed in the fire, and it is uncertain whether it can be volatilized in close vessels. When suffered to cool slowly, it crystallizes in needle-shaped prisms, placed one upon the other, and united in bundles, having a considerable resemblance to masses of basaltes separated from each other: in order to succeed in this crystallization, however, the cobalt must be melted in a crucible till it begins to boil, and, when the surface of the metal becomes fixed on being withdrawn from the fire, the vessel is then to be inclined; that which still remains fluid runs out, and the portion adhering to the lumps formed by the cooling of the surface is found covered with crystals.

1298 Calcines spontaneously in the air.

This semimetal, exposed to the atmosphere, becomes covered with a dull pellicle, and undergoes a spontaneous calcination; but it may easily be calcined in

Cobalt.

in any quantity by expofing it in powder in a fhallow veffel, under the muffle of a cupelling furnace, and ftirring it now and then to expofe frefh furfaces to the air. After being kept red hot for fome time, this powder lofes its fplendor, increafes in weight, and be-
1299 Its calx forms a beautiful blue glafs. comes black, the calx being convertible, by a moft violent heat, into a blue glafs. By fufion it combines with vitrifiable earths, forming with them a beautiful bule glafs extremely fixed in the fire; whence it is of the greateft ufe in enamel-painting, porcelain-painting, &c. The action of terra ponderofa, magnefia, and lime, on cobalt, is not known. Alkalies manifeftly alter it; but in what refpect is not known.

1300 Phenomena with vitriolic acid. Cobalt diffolves in concentrated vitriolic acid, when affifted by a boiling heat; the acid evaporating almoft entirely in the form of fulphureous gas. The refiduum is then to be wafhed; a portion of it diffolves in the water, and communicates a greenifh colour to it when warm, which changes to a rofe colour when cold. M. Beaumé affirms, that by fufficiently evaporating the vitriolic folution of cobalt, two forts of cryftals are obtained; one white, fmall, and cubical; the other greenifh, quadrangular, fix lines in length, and four in breadth. Thefe laft he only confiders as the true vitriol of cobalt; the former being produced by certain foreign matters united to it. The cryftals moft commonly obtained have the form of fmall needles, and may be decompofed by fire, leaving a calx of cobalt not reducible by itfelf. They may likewife be decompofed by all the alkalies, by terra ponderofa, magnefia, and lime. According to Fourcroy, 100 grains of cobalt, diffolved in the vitriolic acid, afford, by precipitation with pure mineral alkali, 140 grains of precipitate; by the fame alkali aërated, 160 grains. Diluted vitriolic acid acts on zaffre, and diffolves a part, with which it forms the falt already defcribed.

1301 With nitrous acid. Nitrous acid acts upon the femimetal with that violence which is its general characteriftic; and the folution, when nearly faturated, appears either of a rofy brown or bright green colour. By ftrong evaporation it yields a falt in fmall needles joined together; which is very deliquefcent, boils upon hot coals without detonation, and leaves a calx of a deep red colour. It is decompofed by the fame fubftances as the former, and by excefs of alkali the precipitate difappears.

1302 With marine acid. Muriatic acid, affifted by heat, diffolves cobalt in part, but has no effect upon it in the cold. It acts more ftrongly on zaffre, forming a folution of a reddifh brown, which becomes green by being heated. By evaporation it yields a very deliquefcent falt in fmall needles, which becomes green when heated, and is foon after decompofed. Aqua-regia diffolves the metal more eafily than the marine acid, but lefs fo than the nitrous. The folution has been long known as a *fympathetic Ink*.

1303 With the acid of borax. Cobalt is not diffolved directly by the acid of borax; but when a folution of this falt is mixed with a folution of cobalt in any of the mineral acids, a double decompofition takes place; the alkaline bafis of the borax uniting with the acid which held the cobalt in folution; and the calx, combining with the fedative falt, falls to the bottom in form of an infoluble precipitate.

This femimetal is calcined by being heated to ignition with nitre. One part of cobalt, and two or three of dry nitre, well powdered and mixed, when thrown into a red-hot crucible; produce fmall fcintillations; a portion of the cobalt being converted into a calx of a red colour, more or lefs deep, and fometimes of a green.

1304 With fal ammoniac. Sal ammoniac is not decompofed, by reafon of the little attraction there is between the metal and muriatic acid. M. Bucquet, who made the experiment with great care, could not obtain a particle of volatile alkali.
1305 With fulphur. Sulphur does not unite with it but very difficultly, and the combination is promoted by liver of fulphur. Thus a kind of artificial one may be produced, the grain of which will be finer or clofer, and its colour whiter or yellower, in proportion to the quantity of fulphur in the mixture. M. Beaumé obferves, that this compound cannot be decompofed by acids, and that fire cannot deftroy all the fulphur.

§ 13. *Nickel.*

1306 Difcovered by Mr Cronftedt. This was firft difcovered to be a femimetal of a peculiar kind by Cronftedt, in the years 1751 and 1754, who procured it in the form of regulus from its ore, but without being able to reduce it to a fufficient degree of purity; which indeed has not yet been done by any chemift. M. Bergman has laboured moft in this way, though even he has not reduced it to the purity of other metallic fubftances. His experiments were made with fome regulus made by M. Cronftedt, and whofe fpecific gravity was to that of water exactly as 7.421 to 1. His attempts to purify it were made,

I. By Calcination and Scorification.

1307 Effects of calcination with a violent heat. Nine ounces of powdered nickel were expofed for fix hours, in feveral portions, to a moft violent heat, under the dome of an affay furnace. Thus the arfenic was firft diffipated with a fetid fmell, after which the odour of fulphur became perceptible; after this a white fmoke arofe without any fmell of garlic, and which, according to our author, arofe probably from the more dephlogifticated part of the arfenic which now began to fublime. The heaps (we fuppofe after the matter had been poured out of the difhes, and yet retaining a great deal of heat), when hot, began to fwell, and green vegetations arofe from all the furface, refembling fome kinds of mofs, or the filiform lichen; a ferruginous afh-coloured powder remained at bottom; and 0.13 of the whole were diffipated during the operation. Half an ounce of this calx fufed in a forge for four minutes, along with three times its weight of black flux, yielded a regulus reticulated on the furface; the areola of a hexangular figure, with very flender ftriæ, diverging from a centre, full of little tubercles; it weighed 0.73 of half an ounce; was obedient to the magnet; and, when fcorified with borax, left a blackifh glafs.

By a fecond roafting the regulus again emitted a garlic fmell; afterwards a vifible fume without any fmell, with vegetations as before. The roafted powder, reduced with black flux as before, ftill emitted a fmell of arfenic; but on repeating the fufion with the calx and borax, nothing but fome obfcure figns of cobalt appeared. A third calcination feemed to have much diffipated the arfenic, as it now emitted but little of that kind of fmell; the vegetations were alfo gone; and the matter had rather a ferruginous than a green

Nickel.

green colour. Nearly the same phenomenon appeared after reduction in a fourth operation.

On performing the reduction with lime and borax, the regulus, when first melted, lost much of its ferruginous matter, which adhered to the black scoriæ; it soon acquired an hyacinthine colour, without any remarkable mixture of cobalt, was little obedient to the magnet, and its specific gravity was somewhat diminished, being now only 7.0828.

By a fifth calcination, gradually adding a quantity of powdered charcoal while the matter continued red hot, a prodigious quantity of arsenic, imperceptible before, flew off in the form of vapour; the arsenical acid being thus furnished with as much phlogiston as was necessary to make it rise in fume. The regulus was treated in this manner until no more arsenical smoke could be perceived; it was now of a lamellated and tenacious texture when reduced, but still diffused the arsenical odour on being removed from the fire. The roasting was therefore repeated a sixth time, and continued for ten hours; the addition of powdered charcoal continued to dissipate the arsenic in invisible vapours which yet were perceptible by the smell; the colour of the metallic calx was obscurely ferruginous, with a mixture of green scarcely visible. On reducing the regulus with equal parts of white flux, lime and borax, a semiductile regulus was obtained, highly magnetic, and soluble in nitrous acid, to which it communicates a deep green colour; a blackish mass remained, which afterwards become white, and when laid on a burning coal, flies off without any remarkable arsenical smell. The regulus being then six times fused with lime and borax, the scoriæ resembled the hyacinth in colour, and the metallic part was surrounded with a green calx. The regulus, as before, was magnetic and semi-malleable. Lastly, it was exposed for 14 hours to a very strong heat; when the powdered charcoal was added by degrees without any dissipation of arsenic or loss of weight; the colour of the roasted powder was ferruginous, with a very slight tinge of green. On reduction, a very small globe, still magnetic, was found among the scoriæ.

II. By Sulphur.

1308 Effects of sulphur and borax.

Eight hundred parts of Cronstedt's regulus of nickel, fused with sulphur and a small quantity of borax, yielded a mineralized mass of a reddish yellow, whose weight amounted to 1700. On exposing one half of this to the fire, it began to grow black; on which the heat was augmented until vegetations appeared; the remaining calx weighed 652. Melting this part with borax, and the other which had not been exposed to the fire, a sulphurated regulus of a whitish yellow colour was obtained, weighing 1102. The same regulus, calcined for four hours, was first covered with vegetations, and then, on the addition of powdered charcoal, diffused an arsenical odour; the metallic calx was green, and weighed 1038. A whitish yellow regulus was obtained semiductile, highly magnetic, and extremely refractory, weighing 594. By fusion with sulphur a second time, it weighed 816; one half of which roasted to greenness, united by means of fire to the other half still sulphurated, weighed 509, and was almost deprived of its magnetic quality. A calcination of four hours, during which phlogiston was added, dissipated a considerable quantity of arsenic; the powder put on an ash-colour, somewhat greenish, was in weight 569; and by reduction yielded a regulus whose surface was red, and which, on breaking, appeared of a white ash-colour, very friable, and weighing 432; the specific gravity 7.173.

On mineralizing the regulus a third time with sulphur, adding charcoal as long as any vestige of arsenic remained, which required a violent calcination of 12 hours, the remaining powder was of an ash-green colour, and weighed 364; but the regulus obtained by means of a reduction effected by the most violent heat in a forge for three quarters of an hour, was so refractory that it only adhered imperfectly to the scoria, which were of a distinct hyacinthine colour; nor could it be reduced to a globule by means of borax, though urged by the same vehemence of fire. The absolute gravity of this regulus was 180; its specific gravity 8.666. Its magnetic virtue was very remarkable; for it not only adhered strongly to the magnet, but to any other piece of iron; and the small pieces of it attracted one another. It had a considerable ductility, was of a whitish colour, mixed with a kind of glittering red; dissolved in volatile alkali, yielding a blue solution, and a green one in nitrous acid.

An hundred parts of the same regulus, beaten out into thin plates, were covered by a calcination of four hours, with a crust apparently martial, having under it a green powder, and within it a nucleus consisting of reguline particles still unchanged; the weight being increased by 5. The friable matter, reduced to powder, put on a brownish-green colour; and after a calcination of four hours more, concreted at the bottom in form of a friable black crust, strongly magnetic, and weighing 100: No vestiges of arsenic were discovered by a succeeding operation, in which charcoal was added; nor was the magnetic powder destroyed, but the weight was increased to 105, and the colour somewhat changed. By fusion for an hour with lime and borax, this powder yielded a regulus of an angular structure, red, semiductile, and altogether magnetic; the specific gravity being 8.875. The same globule dissolved in aqua-regia, was precipitated by green vitriol, as if it had been loaded with gold; but the precipitate was readily soluble in nitrous acid. Most of the reguli showed no signs of precipitation with green vitriol.

III. With Hepar Sulphuris.

Fifty-eight parts of regulus of nickel, which had been sulphurated before, being fused with 1800 parts of saline hepar sulphuris, then dissolved in warm water, filtered through paper, and precipitated by an acid, yielded a powder, which, by calcination till the sulphur was driven off, appeared of an ash-colour, and weighed 35. The insoluble residuum, deprived of its sulphur by means of fire, was likewise of an ash-colour, and weighed 334. On reducing this regulus by means of the black flux, a friable regulus was obtained, which had a very weak magnetic property; but, on fusion with borax, this quality was augmented. On mixing and melting together equal parts of calx of nickel, gypsum, colophony, and white flux, a powdery, squamous, and reguline mass was produced; which, by fusion with borax, afforded a regulus possessing the properties 1309 Effect of hepar sulphuris.

Nickel.

perties of nickel, but not entirely destitute of cobalt, which obeyed the magnet, and did not part with its iron even after two solutions in the nitrous acid, and various reductions by fusion with borax; the sulphur was also retained with great obstinacy.

On dissolving regulus of nickel by fusion, in hepar sulphuris made with fixed alkali, adding a quantity of nitre sufficient only to destroy a small part of the hepar, the regulus which had been suspended by it was separated, and fell to the bottom. On examining this regulus, it appeared more pure, and generally deprived of cobalt, but still containing iron. In like manner nickel is always very distinctly precipitated by regulus of cobalt, as this latter is attracted more powerfully by the hepar sulphuris. When dissolved by fusion with hepar sulphuris, this semimetal may be precipitated by adding iron, copper, tin, or lead, and even by cobalt: the regulus obtained is indeed scarcely ever attracted by the magnet; but we are not from thence to conclude that it does not contain any iron; for when the heterogenous matters, which impede its action, are properly removed, it then acknowledges the power of the magnet very plainly.

IV. By Nitre.

1310 Of nitre. One part of Cronstedt's regulus was added to twelve of nitre ignited in a crucible, and kept red-hot for about an hour. Some weak flashes appeared first; then a large quantity of arsenic was emitted; and, lastly, the sides were covered with a blue crust occasioned by the cobalt, a green matter remaining at bottom. This, fused again for an hour, with twelve parts of nitre, tinged the internal sides of the vessel of a green colour; and, lastly, a brownish green mass, much less in quantity than in the former operation, was left at the bottom. This green matter, treated in the same way for two hours a third time, left a grey scoria at the bottom, which yielded no regulus with black flux.

Another portion of the same regulus, treated in the same way with nitre, was dissolved, and became green; yet on being freed by ablution from the alkaline salt, it yielded no regulus with black flux, but only scoria of an hyacinthine colour mixed with blue, tinging nitrous acid of a green colour, concreting into a jelly, and on evaporation leaving a greenish calx behind.

Another portion of Cronstedt's regulus was kept some hours in the crucible with 16 parts of nitre; by which means all the arsenic was first separated; then the phlogisticated nitrous acid; and, lastly, the sides of the vessel were penetrated by a kind of green efflorescences. The mass, after being washed with water, was of a dilute green colour, and tinged borax of a greenish brown. A green powder was still yielded, after treating this in the same manner with 12 parts of nitre; and on reducing it with one-half black flux, one-eighth borax, and as much lime, a yellowish white regulus, both magnetic and malleable, was obtained, possessing all the properties of nickel. Its specific gravity was 9.000; the phlogistic ingredient was used in small quantity, that the iron might, if possible, enter the scoria.

1311 Nitre capable of separating all the cobalt from nickel. It having appeared from this and some other experiments, that nitre was capable of discovering the smallest quantity of cobalt contained in nickel the products of the former operations were now subjected to its action. The regulus produced by repeated scorification thus became a little blue; that dissolved in volatile alkali (to be afterwards particularly mentioned) discovered a considerable quantity of cobalt; nor was there any one which did not thus discover more or less of that ingredient by this trial.

V. By Sal Ammoniac.

1312 Effect of sal ammoniac. A calx of nickel, so much freed from cobalt that it did not tinge borax in the least, mixed with twice its weight of sal ammoniac, yielded by sublimation with a strong red heat, two kinds of flowers; one, which rose higher than the other, was of an ash colour; the other white. The botton of the glass was stained of a deep hyacinthine colour; the residuum was divided into two strata; the upper one yellow, scaly, and shining like mosaic gold. With borax it afforded an hyacinthine glass, but not regulus; and in a few days liquefied in the air, acquiring a green colour and the consistence of butter. The residuum showed the same properties with calx of nickel; and the green solution showed no vestiges of iron with galls, but became blue with volatile alkali; which was also the case with the flowers. The lower stratum contained a calx, blackish on the upper part, but of a ferruginous brown in the under, with a friable and scarcely magnetic regulus, of a reddish white. The blackish calx yielded an hyacinthine glass with borax. Part of this stratum sublimed with twice its quantity of sal ammoniac; and with the same degree of heat as before, yielded flowers of a very fine white, with a residuum of ferruginous brown, greenish on the upper part towards the sides of the vessel, the bottom being stained of an hyacinthine colour as before. Twenty parts of sal ammoniac being added to a part of the inferior stratum reduced, the whole was sublimed in a retort; a blackish powder remained, which became green by calcination, and of an hyacinthine colour by scorification, as did also the bottom of the containing vessel. The sublimation being twice repeated, using a double quantity of sal ammoniac each time, the calx became at length very green, dissolving with the same colour in the nitrous acid, and yielding by reduction a white, brittle, and very little magnetic regulus. In all these sublimations, it was observed, that the volatile alkali rose first; then sal ammoniac; and, lastly, a part of the marine acid was forced over by the violence of the heat.

VI. With Nitrous acid.

1313 Effects of antimony. Having obtained a salt by crystallization from nickel dissolved in nitrous acid, part of this was calcined with charcoal dust in a proper vessel, and during the operation a large quantity of arsenic was dissipated; a grey, semiductile, and magnetic regulus being obtained after reduction. A brittle regulus was obtained after a second solution, precipitation, and reduction; but by a third operation it became again semiductile and magnetic. By repeating this process a fourth and fifth time, the quantity became so much diminished that it could no longer be tried. In all these solutions a blackish residuum appeared; which, when suffered to remain in the acid, grew white by degrees; but when edulcorated and laid on a burning coal, exhaled a sulphureous smoke, and left a black powder soluble in the nitrous acid.

VII. By

Nickel.

VII. By volatile Alkali.

1314 Volatile alkali. Four hundred and eighty-seven parts of a calx of nickel, produced by diſſolving Cronſtedt's regulus in nitrous acid, and precipitating the ſolution by a fixed alkali, being immerſed for 24 hours in a quantity of volatile alkali, yielded a reſiduum of fifty, having a blackiſh green colour. The ſolution, which was blue, by filtration and inſpiſſation yielded a powder of a light blue colour, weighing 282; which, reduced with black flux, produced a white, ſemiductile, and highly magnetic regulus, weighing 35, whoſe ſpecific gravity was 7.000. The ſcoriæ were of a light red: but when mixed with borax, put on an hyacinthine colour, and yielded a regulus weighing 30. The two reguli united together proved very refractory; ſo that the maſs could not be melted by the blow-pipe, even with the addition of borax. It ſent forth neither an arſenical nor ſulphureous ſmell on the addition of charcoal-duſt; but, on a ſucceeding reduction, yielded hyacinthine ſcoriæ; and the remaining flocculi, diſſolved in nitrous acid, affording a very green ſolution, which, on the addition of volatile alkali, yielded a powder of the ſame colour.

From 50 parts of the blackiſh green reſiduum, 13 of a clear white, brittle, ſquamous, and little magnetic regulus, were obtained, the ſpecific gravity of which was 9.333. At the bottom of the veſſel was found a ſcoria of an obſcurely blue colour, with the upper part hyacinthine. It was eaſily fuſed; and tinged borax, firſt blue, then of a hyacinth colour, upon which it became more ſtrongly magnetic. By the aſſiſtance of heat it diſſolved in nitrous acid, forming a ſolution of a beautiful blue colour. A black powder at firſt floated in the liquor, but became white, and fell to the bottom. After edulcoration it was for the moſt part diſſipated, with a ſulphureous ſmell, on being expoſed to the fire; a little brown-coloured maſs, ſoluble in volatile alkali, remaining at bottom. This ſolution was precipitated by phlogiſticated alkali, and a powder thrown down of the colour of calx of nickel, which ſoon grew blue with volatile alkali.

1315 Nickel cannot be obtained in a ſtate of purity. From all theſe experiments it appears, that nickel cannot be obtained in a ſtate of purity by any means hitherto known. From every other ſubſtance, indeed, it may be ſeparated, except iron; but this reſiſts all the operations hitherto deſcribed, and cannot be diminiſhed beyond certain limits. The magnet not only readily diſcovers its preſence, but ſome portions of the regulus itſelf becomes magnetic; but the tenacity and difficulty of fuſion, which increaſe the more in proportion to the number of operations, plainly ſhow that there is no hope of ſeparating the whole quantity, unleſs we ſuppoſe the regulus of nickel itſelf to be attracted by the magnet; and there is certainly a poſſibility that one other ſubſtance beſides iron may be attracted by the magnet. The great difficulty, or rather impoſſibility, of obtaining it in a ſtate of purity, naturally raiſes a ſuſpicion of its not being a diſtinct

1316 Bergman's opinion of the compoſition of nickel. ſemimetal, but a mixture of others blended together; and on this ſubject our author agrees in opinion with thoſe who ſuppoſe it to be a compound of other metals. Indeed, Mr Bergman is of opinion, that "nickel, cobalt, and mangaueſe, are perhaps no other than modifications of iron." And in order to aſcertain this, he made the following experiments.

1317 Experiments to compoſe nickel artificially. 1. Equal parts of copper, of the gravity of 9.3243, and iron of 8.3678, united by fuſion with black flux, yielded a red maſs, whoſe ſpecific gravity was 8.5441; and which tinged nitrous acid firſt blue, then green, afterwards yellow, and at laſt of an opaque brown. 2. Two parts of copper and one of iron had a ſpecific gravity of 8.4634; the mixture yielding firſt a blue, and then a green ſolution. 3. Equal parts of copper and iron, of the ſpecific gravities already mentioned, with another part of cobalt whoſe gravity was 8.1500, yielded a metal of the gravity of 8.0300, imparting a brown colour to the ſolution. 4. Two parts of arſenic of 4.000, added to one of copper and another of iron, gave a brittle metal of 8.0468, which formed a blue ſolution. 5. One part of copper, one of iron, two of cobalt, and two of white arſenic, gave a brittle regulus of 8.4186; the ſolution of which was browniſh, and ſeparated in part ſpontaneouſly. 6. One part of copper, one of iron, four of cobalt, and two of white arſenic, formed a maſs of 8.5714. The ſolution was ſomewhat more red than the former; and a ſimilar effect took place on repeating the experiment, only that the ſpecific gravity of the metal was now 8.2941. 8. One part of iron and four of white arſenic formed a metal which diſſolved with a yellow colour; and, on the addition of Pruſſian alkali, immediately let fall a blue ſediment. 9. One part of copper, eight of iron, ſixteen of white arſenic, and four of ſulphur, united by fire, on the addition of black flux, yielded a maſs which, though frequently calcined and reduced, produced nothing but brown or ferruginous calces. It acquired a greenneſs with nitrous acid; but on the addition of phlogiſticated alkali depoſited a Pruſſian blue. 10. One part of iron was diſſolved in ſix of the nitrous acid, and likewiſe ſeparated by one part of copper and one of the calcined ore of cobalt, in the ſame quantity of the ſame acid. The whole of the ſolution of iron was then mixed with five parts of the ſolution of copper, whence a green and ſaturated nickel colour was produced; which, however, on the addition of three parts of the ſolution of cobalt, became evidently obſcured. The alkaline lixivium dropped into this threw down at firſt a ferruginous brown ſediment, the ſolution ſtill remaining green: afterwards all the blue was precipitated; by which at firſt all colour was deſtroyed, but afterwards a red appeared, occaſioned by the cobalt diſſolved in the alkaline ſalt. The ſediment, when reduced, yielded a regulus ſimilar to copper, and at the ſame time ductile, which tinged both glaſs and nitrous acid of a blue colour. If a ſaturated ſolution of nickel be mixed with half its quantity of ſolution of cobalt, the green colour is much obſcured; but four parts of the former, on the addition of three of the latter, put off all appearances of nickel. See the article NICKEL.

§ 14. *Of Platina.*

1318 The heavieſt of all metals. THE properties of this metal have not as yet been thoroughly inveſtigated by chemiſts, and there is therefore ſome diſagreement concerning them. Formerly it was ſuppoſed to be inferior in ſpecific gravity to gold;

gold; but now is generally allowed to be ſuperior in that reſpect by little leſs than a fourth part; being to water in the proportion of 23 to 1 when perfectly freed from all heterogeneous matters. Mr Bergman ſays that its colour is that of the pureſt ſilver. The very ſmall globules of it are extremely malleable; but when many of theſe are collected together,

1319 Inſoluble except by dephlogiſticated marine acid.

they can ſcarcely be ſo perfectly fuſed as to preſerve the ſame degree of malleability. They are not affected by the magnet in the leaſt, nor can they be diſſolved in any ſimple menſtruum excepting dephlogiſticated marine acid. As it is commonly met with, however, platina has the form of ſmall grains, its

1320 Found in ſmall grains intermixed with foreign ſubſtances.

plates of a bluiſh black, whoſe colour is intermediate betwixt thoſe of ſilver and iron. Theſe grains are mixed with many foreign ſubſtances, as particles of gold, mercury, and blackiſh ferruginous, ſandy grains, which by the magnifier appear ſcorified. The grains themſelves, when examined by a magnifying glaſs, appear ſometimes regular, ſometimes round and flat, like a kind of button. When beat on the anvil, moſt of them are flattened and appear ductile; ſome break in pieces, and on being narrowly examined appear to be hollow, and particles of iron and a white powder have been found within them: and to theſe we muſt attribute the attraction of platina by the magnet; ſince, as we have already obſerved, pure platina is not attracted by it.

1321 Mr Bergman's experiments on this metal.

Mr Bergman, who carefully examined this metal, diſſolved it firſt in aqua-regia compoſed of the nitrous and marine acid. The ſolution at firſt exhibits a yellow colour, but on approaching to ſaturation became red, and the redneſs increaſes as the liquor becomes more loaded with metal. Cryſtals are produced by evaporation of a deep red colour, generally in ſmall angular and irregular grains, whoſe true ſhape cannot be diſcovered. Their appearance is ſometimes opaque and ſometimes pellucid. After theſe are once formed, they are extremely difficult of ſolution, requiring much more water than even gypſum itſelf for this purpoſe.—The ſolution is not precipitated by vegetable fixed alkali, nor does the latter affect the cryſtals, except very faintly by digeſtion with them in a cauſtic ſtate. Aerated mineral alkali takes them up and grows yellow, but without depoſiting any thing, though it decompoſes them at laſt by evaporating to dryneſs.

1322 Cryſtals of platina may be decompoſed by mineral but not vegetable fixed alkali.

On the addition of a ſmall quantity of vegetable fixed alkali, either mild or cauſtic, ſmall red cryſtals ſoluble in water, and ſometimes of an octohedral figure, are depoſited. They are decompoſed with difficulty by the mineral alkali, but not at all by the vegetable. If a larger quantity of ſalt is added at firſt, an inſoluble ſpongy matter of a yellow colour is precipitated. Cryſtalline particles of the ſame kind are thrown down by an alkali ſaturated either with the vitriolic, nitrous, marine, or acetous acids, though all the platina cannot thus be ſeparated from the menſtruum.

1323 Solution in aqua-regia made with nitrous acid and that of ſea-ſalt.

Aqua-regia, compoſed of nitrous acid and common ſalt, diſſolved the metal with equal facility as the former; only the ſolution was more dilute, and a yellow powder floated on the ſurface, a larger quantity being found at the bottom. On adding vegetable fixed alkali to the clear ſolution, a copious yellow powder, ſoluble in a large quantity of water, was depoſited. A powder, of a ſimilar kind, was precipitated, tho' more ſlowly, and more of a cryſtalline nature; but mineral alkali, though uſed in much larger quantity, did not make any alteration. The collected powder was yellow, and agreed in property with that ſeparated ſpontaneouſly in a former experiment.

1324 In a liquor compoſed of nitre and ſpirit of ſalt.

On repeating the experiment with nitre and depurated ſpirit of ſalt, inſtead of nitrous acid and ſea-ſalt, the platina was diſſolved into gold-coloured liquor, a greeniſh coloured granulated matter falling to the bottom, and the finer part of the ſame riſing to the top. After ſaturating the ſuperfluous acid, a metallic calx, inſoluble in water, was thrown down by the vegetable alkali. The green powder is ſoluble in water, and is of the ſame nature with the precipitate thrown down by the vegetable alkali.

1325 Cryſtalline powder precipitated by vegetable alkali from ſolution of the calx in marine acid;

Platina precipitated from aqua-regia by a ſufficient quantity of mineral alkali, the precipitate waſhed and diſſolved in marine acid, on the addition of vegetable alkali immediately lets fall a cryſtalline powder, as it does alſo with nitre and other ſalts, having the vegetable alkali for their baſis. The caſe is the ſame with calx of platina, diſſolved in vitriolic acid. Nitrous acid alſo diſſolves the calx of platina, but does not yield any diſtinct ſaline precipitate without the aſſiſtance of marine

1326 But not from the ſolution in nitrous acid.

acid.—The above phenomena are likewiſe produced by the precipitate thrown down by the vegetable alkali after the ſaline powder has been depoſited.

1327 This precipitate a kind of triple ſalt.

From theſe experiments our author concludes, 1. That the precipitate which is firſt thrown down, on the addition of vegetable alkali to ſolutions of platina, is a ſaline ſubſtance, and different from the calx of the metal. 2. That this ſaline precipitate is compoſed of calcined platina, marine acid, and vegetable alkali. 3. By means of vitriolic acid, a precipitate analogous to this may be obtained, compoſed of calcined platina, vegetable alkali, and vitriolic acid. 4. The whole ſolution of platina cannot be precipitated by vegetable alkali in form of a triple ſalt; but after paſſing a certain limit, a metallic calx in the uſual way is produced.

1328 Whether mineral alkali can ſeparate platina from its ſolvent.

As it has been denied by Margraaf and Lewis that mineral alkali is capable of ſeparating platina from its acid, our author was induced to attend particularly to this circumſtance. Having therefore tried the common ſolution with mineral alkali, he found that each drop excited a violent efferveſcence, and at laſt that a yellow ſpongy matter, affording a genuine calx of platina, was precipitated: this was more ſpeedily effected by uſing the dry mineral alkali, which had fallen to powder of itſelf. To determine, however, the difference betwixt the two alkalies in a more accurate manner, he divided a very acid ſolution of platina into two equal parts. To one of theſe, he added ſmall portions of the vegetable, and to the other an equal weight of pieces of mineral alkali, waiting five minutes after every addition, till the efferveſcence ſhould fully ceaſe. After the firſt addition, ſmall cryſtals appeared; in the former partly on the ſurface, and partly

1329 Fifty-ſix times as much mineral alkali required to precipitate platina as of vegetable alkali.

in the bottom; but in the latter no precipitate could be obſerved until 56 times the quantity of vegetable alkali had been added. The difference, however, was even greater than what appears from this experiment; for the vegetable alkali was cryſtallized, and therefore charged with the water neceſſary to its cryſtalline form;

Platina.

form; whereas the mineral alkali was ſpontaneouſly calcined: and though, in equal quantities of theſe two alkalies, the purely alkaline parts are as 3 to 2, yet three parts of vegetable alkali ſaturated only 1.71 of this aqua-regia, while two of the mineral alkali took up about 2.6.

1330 Effects of the volatile alkali.

The volatile alkali firſt throws down this metal in a ſaline form; the grains ſometimes diſtinctly octohedral. Their colour is red when that of the ſolution is ſo, but yellow when the ſolution is more dilute. After ſaturating the ſuperabundant acid, the ſame alkali precipitates the platina truly calcined. This precipitate is diſſolved in water, though with difficulty, and may be reduced to more regular cryſtals by evaporation. Theſe are diſſolved by the mineral alkali; but hardly any ſigns of decompoſition are to be obſerved, unleſs the yellow ſolution, evaporated to dryneſs, be again diſſolved in water; for then the metallic calx reſts at the bottom, and the ſolution is deprived of its yellow colour. The vegetable alkali has ſcarce any effect in this way; for, after repeated exſiccation, the ſolution remains clear and yellow: but here probably the fixed alkali takes the place of the volatile; for in larger quantities, and eſpecially when the cauſtic vegetable alkali is made uſe of, the mixture ſmells of volatile alkali.

1331 Platina partly precipitated by neutral ſalts.

The volatile alkali, ſaturated with any acid, precipitates the platina in the ſame manner as the vegetable alkali in combination with acids: but theſe neutral ſalts precipitate only a determined quantity of platina; for after their effect has ceaſed, the liquor lets fall a pure calx of platina on the addition of vegetable or volatile alkali.

1332 Triple ſalts formed by this metal.

The calx of platina precipitated by mineral alkali, and then diſſolved in any ſimple acid, ſhows nearly the ſame phenomena with volatile alkali as with the vegetable alkali. "Whence (ſays Mr Bergman) we may conclude, that platina diſſolved in acids forms at firſt, both with the volatile and fixed vegetable alkali, a triple ſalt, difficult of ſolution, and which therefore almoſt always falls to the bottom unleſs the quantity of water be very large." Calcareous earth, whether aerated or cauſtic, produces the ſame phenomena as the mineral alkali, without any cryſtalline appearance.

1333 Platina the moſt infuſible ſubſtance in the world.

Platina has been remarkable ever ſince its firſt diſcovery for being the moſt infuſible ſubſtance in the world. Meſſrs Macquer and Beaumé kept it in the moſt violent heat of a glaſs-houſe furnace for ſeveral days without perceiving any other alteration than that its grains adhered ſlightly to each other; but the adheſion was ſo ſlight that they ſeparated even by touching. In theſe experiments the colour of the platina became brilliant by a white heat, but acquired a dull grey colour after it had been heated for a long time. They obſerved alſo, that its weight was conſtantly increaſed: which undoubtedly aroſe from the calcination of the iron it contained. Dr. Lewis, after various attempts to fuſe platina, found himſelf unable to ſucceed even in a fire which vitrified bits of glaſs-houſe

1334 Firſt melted by a burning mirror.

pots and Heſſian crucibles. Meſſrs Macquer and Beaumé firſt melted this refractory metal with a large burning-glaſs, 22 inches diameter and 28 inches focus. The power of this ſpeculum was almoſt incredible, and far exceeded what is related of the lens of Tſchirnhauſen or the mirror of Villette. Its general effects are related under the articl *Burning-Glaſs*. And as platina reſiſted this intenſe heat more than ſix times as long as the moſt unfuſible ſubſtances formerly known, it appears to require a fire as many times ſtronger to melt it.

1335 May be vitrified by electric fire.

It has been found, however, capable not only of fuſion but of vitrification by the electric fire; and that it may alſo be melted by fire excited by dephlogiſticated air: but M. de Liſle was the firſt who was able to melt it with the heat of a com-

1336 Its precipitate fuſible in a common forge.

mon forge when expoſed to the blaſt of a double bellows in a double crucible. Thus its real ſpecific gravity began firſt to be known. It muſt be obſerved, however, that this fuſion was not performed on common platina, but on ſuch as had been diſſolved in aqua-regia and precipitated by means of ſal ammoniac. M. Morveau repeated the experiment, and from 72 grains of platina obtained a regulus weighing 50½; which ſeemed to have undergone a very imperfect fuſion; for it did not adhere to the crucible or take its form, but ſeemed to be merely platina revived. Its ſpecific gravity was alſo found to be no more than 10.045; but it was nearly as malleable as ſilver; and when it had been ſufficiently hammered, its ſpecific gravity was augmented to no leſs than 20.170, which is more

1337 This precipitate, or even crude platina, fuſible by the aſſiſtance of fluxes.

than that of gold itſelf. M. Morveau found that he could melt the precipitate with different fluxes, ſuch as a mixture of white glaſs, borax, and charcoal, and a mixture of white glaſs and neutral arſenical ſalt: and that the regulus thus obtained was more completely fuſed, but was not malleable, and obeyed the magnet; but the regulus obtained without addition did not ſhow this mark of containing iron. He alſo found, that by means of the abovementioned flux of white glaſs, borax, and charcoal, he could melt crude platina. Since that time the fuſion of platina has been accompliſhed by various chemiſts, and with different fluxes; and in proportion to the degree of purity to which the metal has been reduced, its ſpecific gravity has alſo increaſed; ſo that it is now ſettled at 23, that of fine gold being 19.

1338 Alloyed by Dr Lewis with other metals.

Though Dr Lewis could not accompliſh the fuſion of platina by the methods he attempted, he was nevertheleſs able to alloy it with other metals. Equal parts of gold and platina may be melted together by a violent fire, and the mixed metal formed into an ingot by pouring it into a mould. It is whitiſh, hard, and may be broken by a violent blow; but when carefully annealed, is capable of conſiderable extenſion

1339 With gold.

under the hammer. Four parts of gold with one of platina form a compound much more fuſible than the former, and likewiſe more malleable; ſo that it may be extended into very thin plates without being broken or even ſplit at the edges. Dr Lewis remarks alſo, that though in this caſe it be alloyed with ſuch a quantity of white metal, it nevertheleſs appears no paler than guineas uſually are, which contain only one-twelfth of ſilver.

1340 With ſilver.

Equal parts of ſilver and platina melted together with a violent fire, form a much harder and darker-coloured maſs than ſilver, which has alſo a large grain, though it preſerves ſome ductility. Seven parts of ſilver with one of platina form a compound much more reſembling ſilver than the other; but ſtill coarſer-grained and leſs white. From the experiments made on ſilver, however, it appears that no perfect union is

formed

Platina.

formed betwixt the two; for after the mixture has been kept in fuſion for a conſiderable time, moſt of the platina ſeparates and falls to the bottom. Lewis obſerved that ſilver melted with platina was thrown up with an exploſion againſt the ſides of the crucible.

Silver did not appear to be in any degree meliorated by its union with this metal, excepting by the ſuperior

1341 Copper conſiderably improved by union with platina.

hardneſs communicated to it; but copper ſeemed to be conſiderably improved. A large proportion of platina, indeed, as two-thirds or equal parts, produced an hard, brittle, and coarſe-grained compound; but when a ſmaller quantity of platina is added, as from $\frac{1}{6}$ to $\frac{1}{25}$, or even leſs, a golden-coloured copper is produced, very malleable, harder, ſuſceptible of a finer poliſh, ſmoother-grained, and much leſs ſubject to calcination and ruſt than pure copper.

1342 Unites moſt readily with zinc;

Of all metallic matters, however, zinc moſt readily unites with platina, and is moſt effectually diſſolved by fuſion. When the proportion of platina is conſiderable, the metal is of a bluiſh colour, the grain cloſer, without tarniſhing or changing colour in the air, and they have not even the malleability of the ſemimetal.

1343 And with the compound metals.

Platina unites readily with the compound metals, braſs formed of copper and zinc, and bronze made of copper and tin. In the latter it was remarkable, that the compound metal took up more platina than both its ingredients ſeparately can do. This compound was hard and capable of receiving a fine poliſh, but is ſubject to tarniſh.

1344 The compound of braſs and platina a proper material for ſpeculums.

Equal parts of braſs and platina formed a compound very hard, brittle, capable of receiving a fine poliſh, and not ſubject to tarniſh. It is poſſible therefore that it might be uſed to advantage as a material for ſpeculums; all materials for which, hitherto diſcovered, have the great inconvenience of tarniſhing in the air, and that very quickly.

1345 Can ſcarce be united with mercury.

Platina amalgamates with mercury, but with much greater difficulty than gold, which will alſo ſeparate the quickſilver after it has been united with the platina. The amalgamation of platina does not ſucceed but by very long trituration of the metals with water,

1346 Mercury leaves platina to unite with gold.

as for inſtance a week; but if the trituration be performed with a mixed metal compoſed of gold and platina, the mercury ſeizes the gold, and leaves the platina untouched. Dr Lewis propoſes this as a method of ſeparating gold from platina; and it is that uſed in Peru, where gold and platina are ſometimes naturally mixed in the ore; but we do not know whether this ſeparation be quite complete.

1347 May be united with forged and caſt iron;

Mr Morveau ſucceeded in uniting iron with platina, though Dr Lewis could not accompliſh this. The latter ſucceeded, however, in uniting it with caſt iron. The compound was much harder and leſs ſubject to ruſt than pure iron. It was alſo ſuſceptible of a much finer poliſh.

1348 And with tin, lead, or biſmuth.

Platina may be alloyed with tin, lead, or biſmuth, but without any advantage. To lead and tin it gives the property of aſſuming blue, violet, or purple colours, by being expoſed to the atmoſphere.

Dr Lewis could not ſucceed in uniting platina with arſenic; but M. Scheffer affirms, that if only one twentieth of arſenic be added to platina when red hot in a crucible, the two ſubſtances will be perfectly fuſed and united into a brittle grey maſs. This experiment did not ſucceed with Mr Margraaf; for he, having expoſed to a violent fire during an hour a mixture of an ounce of platina with a fuſible glaſs, compoſed of eight ounces of minium, two ounces of flints, and one ounce of white arſenic, obtained a regulus of platina well united and fuſed, weighing an ounce and 32 grains; the ſurface of which was ſmooth, white, and ſhining, and the internal parts grey; but which nevertheleſs appeared ſufficiently white when filed. The experiment ſucceeded imperfectly alſo in the hands of Dr Lewis; but M. Fourcroy informs us, that "it has ſince been repeated, and that platina is in fact very fuſible with arſenic, but that it remains brittle. In proportion as the arſenic is driven off by the continuance of the heat, the metal becomes more ductile; and by this proceſs it is that M. Achard and M. de Morveau ſucceeded in making crucibles of platina by melting it a ſecond time in moulds." (A)

1349 May be melted by means of arſenic.

1350 Fourcroy denies that platina can be united with mercury.

M. Fourcroy ſeems to deny that platina can be united with mercury, contrary to what is mentioned above. "Platina (ſays he) does not unite with mercury, though triturated for ſeveral hours with that metallic fluid. It is likewiſe known, that platina reſiſts the mercury uſed in America to ſeparate the gold. Many intermediums, ſuch as water, uſed by Lewis and Beaumé, and aqua-regia by Scheffer, have not been found to facilitate the union of theſe two metals. In this reſpect platina ſeems to reſemble iron, to whoſe colour and hardneſs it likewiſe in ſome meaſure approaches." This laſt ſentence, however, ſeems very little to agree with what he himſelf had before told us

1351 Inconſiſtent in his account of its hardneſs.

of M. Macquer's experiment of melting platina. "The melted portions (ſays he) were of a white brilliant colour, in the form of a button; they could be *cut to pieces* with a knife." This ſurely was a very ſmall approach to the hardneſs of iron; and gives us an idea rather of the conſiſtence of tin or lead. "One of theſe maſſes was flattened on the anvil, and converted into a thin plate without cracking or breaking, but it became hard under the hammer." In another experiment indeed the button of platina was brittle, and ſufficiently hard to make deep traces in gold, copper, and even iron; but this was obtained from precipitated platina urged for 35 minutes by a ſtrong blaſt furnace. In an experiment of this kind M. Beaumé even ſucceeded in melting the precipitate along with certain fluxes, into a vitriform ſubſtance by two different proceſſes. The precipitate of platina, mixed with calcined borax, and a very fuſible white glaſs, was expoſed, for 36 hours, in the hotteſt part of a potter's furnace; and afforded a greeniſh glaſs, inclining to yellow, without globules of reduced metal. This glaſs, treated a ſecond time with cream of tartar, gypſum, and vegetable alkali, was completely melted, and exhibited globules of platina diſperſed through its ſubſtance. M. Beaumé ſeparated them by waſhing, and found them ductile. The ſame chemiſt afterwards, together

1352 Precipitated platina vitrified by M. Beaumé

(A) For a particular account of this proceſs ſee before n° 587.

Platina. gether with M. Macquer, expofed precipitate of platina to the fame burning mirror with which they had fufed the metal: the precipitate exhaled a very thick and luminous fume, with a ftrong fmell of aqua-regia: it loft its red colour, refumed that of platina, and melted into a perfect brilliant button, which was found to be an opaque vitreous fubftance, of an hyacinthine colour at its furface, and blackifh within; and may be confidered as a true glafs of platina. It may however be obferved, that the faline matters with which it was impregnated contributed doubtlefs to its vitrification.

"The orange-coloured precipitate obtained by pouring a folution of fal ammoniac into a folution of platina, appears to be a faline fubftance entirely foluble in water. This precipitate has a valuable property, difcovered by M. de l'Ifle, viz. that it is fufible without addition in a good furnace or common forge-heat. The platina melted by this procefs is a brilliant, denfe, and clofe-grained button; but it is not malleable unlefs it has been expofed to a very ftrong heat. Macquer thinks that this fufion, like that of the grains of platina alone, expofed to the action of a violent fire, confifts only in the agglutination of the foftened particles; which being exceedingly more divided and minute than the grains of platina, adhere to and touch each other in a greater number of points than the grains; and in that manner render the texture of the metal much more denfe, though no true fufion may have taken place. It feems, however, that if platina in grains be capable of fufion by the burning-glafs, and of becoming confiderably ductile, the precipitate of this metal, formed by fal ammoniac may likewife be fufed on account of its extreme divifion; and that its not being as ductile as the button of platina fufed by the folar heat, may perhaps depend on its retaining a part of the matter it carried down with it in precipitation, of which it may be poffible to deprive it by fire."

1353 Precipitate by fal ammoniac fufible in a ftrong forge heat.

1354 This fufion fuppofed by Macquer not to be perfect.

1355 Attempts to purify platina by cupellation

It being fo extremely difficult to bring platina itfelf into fufion, one of the firft attempts to purify it was by cupellation with lead. Thus the bafer metals would be fcorified; and, running through the crucible along with the lead, leave the platina in as great purity as though it had been melted by itfelf. This operation, however, was found almoft equally difficult with the fufion of the metal by itfelf. Lewis failed in the experiment, though he applied the moft violent heat of the ordinary cupelling furnaces. The vitrification and abforption of the lead indeed took place as ufual; but in a fhort time the platina became fixed, and could not by any means be rendered fluid. Meffrs Macquer and Beaumé fucceeded by expofing an ounce of platina with two ounces of lead in the hotteft part of a porcelain furnace, where the fire is continued for 50 hours without intermiffion. At the end of the operation the platina was flattened in the cupel; its upper furface was dull and rough, and eafily feparated; but its under furface was brilliant, and it was found eafily to extend under the hammer; and on every chemical trial was found to be perfectly pure, without any mixture of lead. M. de Morveau likewife fucceeded in cupelling a mixture of one drachm of platina and two drachms of lead in M. Macquer's wind-furnace. The operation lafted eleven or twelve hours, and a button of platina was obtained which did not adhere to the cupel, was uniform, though rather rough, and of a colour refembling tin.' It weighed exactly one drachm, and was not at all acted upon by the magnet. Thus it appears that platina may be obtained in plates or laminæ, which may be forged, and confequently may be employed in making very valuable utenfils; and this the more efpecially as Mr Beaumé has obferved that different pieces of it may be welded and forged like iron. After having heated two pieces of pure cupelled platina to whitenefs, he placed them one upon the other, and ftriking them brifky with a hammer, found that they united together as quickly and firmly as two pieces of iron would have done. Platina.

1356 Of the poffibility of adulterating gold with platina.

The great fpecific gravity of platina has rendered it a very defirable matter for fuch as wifh to adulterate the precious metal, and can procure the platina eafily. This, however, can only be done in South America, where platina is met with in plenty. In Europe the fcarcity of platina renders it a more valuable object than even the gold itfelf. Fears of this fraud, however, have undoubtedly given occafion to the prohibition of exporting it. There are great differences among chemifts concerning the quantity of platina that can be mixed with gold without deftroying the colour of the latter. Dr Lewis, as has already been obferved, informs us, that four parts of platina may be mixed with one of gold, and yet the mixture be no paler than that for guineas; while Fourcroy afferts, that "it greatly alters the colour of the metal, unlefs its quantity be very fmall: thus, for example, a 47th part of platina, and all the proportions below that, do not greatly affect the colour of the gold." But whether this be the cafe or not, chemiftry has afforded various ways of feparating even the fmalleft proportion of platina from gold; fo that there is now no reafon to prohibit the importation of it to Europe, more than that of any other metal with which gold can be alloyed. The following are the methods by which the platina may be moft readily difcovered: 1. By amalgamating the fufpected metal with mercury, and grinding the mixture for a confiderable time with water; by which the platina will be left, and the gold remain united with the quickfilver. 2. By diffolving a little of it in aqua-regia, and precipitating with alkaline falt; the remaining liquor, in cafe the metal has been adulterated with platina, will be fo yellow, that it is fuppofed a mixture of one thoufandth part would thus be found out. 3. By precipitation with fal ammoniac, which throws down the platina but not the gold. If mineral alkali be ufed, the gold will be precipitated, but not the platina, unlefs the precipitant is in very large quantity. 4. By precipitation with green vitriol, which throws down the gold, and leaves the platina united with the menftruum.

1357 Methods of detecting this fraud if it fhould be practifed.

1358 Platina moft eafily difcoverable by its great fpecific gravity.

All thefe methods, however, are not only attended with a confiderable deal of trouble, but in fome cafes, for inftance in fufpected coin, it might not be eligible to ufe them. The hydroftatic balance alone affords a certain method of difcovering mixtures of metals without hurting the texture of their parts. The great fpecific gravity of platina would very readily difcover it if mixed with gold in any moderate quantity; and even in the fmalleft, the gravity of the mafs could never be lefs than that of the pureft gold: which circumfta n

Manganese cumstance alone, as gold is never worked without alloy, would be sufficient to create a just suspicion; after which some of the methods already mentioned might be tried. It is possible, however, that the hardness and ductility of platina might render it more proper for alloying gold than even copper or silver, usually made use of for this purpose.

§ 15. *Of Manganese.*

1359 New semi-metal afforded by manganese. This substance is now discovered to afford a semi-metal different from all others, and likewise to possess some other properties of a very singular kind. Mr Scheele has investigated its nature with the utmost care; and the result of his inquiries are as follows:

1360 Properties of the common manganese treated with vitriolic acid. 1. Two drachms of levigated manganese, digested for several days in a diluted vitriolic acid, did not appear to be dissolved or diminished in quantity; nevertheless a yellowish white precipitate was procured by saturating the acid with fixed alkali. The remaining manganese was not acted upon by more of the same acid, but the addition of another half ounce nearly destroyed the acidity of the menstruum when boiled upon it.

2. With concentrated vitriolic acid an ounce of manganese was reduced to a mass like honey, and then exposed to the fire in a retort till it became red-hot. Some vitriolic acid came over into the receiver; and after breaking the retort, a mass was found in it weighing 12¼ drachms, hard and white in the inside, but red on the outside. A great part of it dissolved in distilled water, on the affusion of which at first it became very hot. The residuum after edulcoration weighed a drachm and an half, and was of a grey colour. Being calcined in a crucible with concentrated vitriolic acid till no more vapours arose, it was all dissolved by water excepting one drachm; which being again calcined with the same acid, an insoluble residuum of a white colour, and weighing only half a drachm, remained. This white residuum effervesced with borax, and melted into a transparent brown glass; it likewise effervesced with fixed alkali, changing into a brown mass, which yielded an hepatic smell with acids, and became at the same time gelatinous. The solution obtained by calcination was evaporated and set to crystallize. A few small crystals of selenite were first deposited, and afterwards some very fine large crystals of an oblique parallelopiped form, whose number increased as long as there was any liquid left. They tasted like Epsom salt, and Mr Westfeld supposes them to be alum; but according to Mr Scheele, they have no other resemblance to alum than that they contain the vitriolic acid.

1361 Entirely dissolved by phlogisticated vitriolic acid. 3. By phlogisticated vitriolic acid the manganese was entirely dissolved. To procure this acid in purity, Mr Scheele dipped some rags in a solution of alkali of tartar, and after saturating them with the fumes of burning brimstone, put them into a retort, pouring on them some dissolved acid of tartar, luting on a receiver which contained levigated manganese and water. After a warm digestion of only one day, the liquid of the receiver had become as clear as water, and a little fine powder, consisting principally of siliceous earth, fell to the bottom.

4. Two drachms of levigated manganese, digested for several days with an ounce of pure colourless acid of nitre, did not appear to have deprived the menstruum of its acidity, or to have been affected by it in any degree. The liquor being distilled off, and the product of the distillation poured back on the residuum, a small quantity of it was dissolved. By a third distillation, and pouring back the liquor on the residuum, a complete solution was effected; and this quantity of acid appeared capable of dissolving nine drachms of the powder.

5. The solution of manganese thus saturated, was filtered and divided into two equal portions. Into one of these some drops of vitriolic acid were poured, by which a fine white powder was thrown down, which, however, did not settle to the bottom for some hours. It was soluble neither in boiling water nor in acids. The limpid solution, by evaporation, yielded some small crystals of selenite or gypsum. 1362 Precipitate and crystals obtained from the solution.

6. From the other half of this solution, after evaporation by a gentle heat, about ten grains of small shining crystals of a bitter taste were obtained. On pouring some drops of vitriolic acid into the solution inspissated by gentle heat, no precipitation, excepting of a little selenite, ensued; but as soon as it was inspissated to the consistence of honey, some fine acicular crystals, verging towards the same centre, began to form, but grew soft, and deliquesced in a few days after.

7. Phlogisticated nitrous acid dissolves manganese as readily as the phlogisticated vitriolic. A little levigated manganese mixed with some water was put into a large receiver, to which a tubulated retort was luted. Some ounces of common nitrous acid were put into the retort, to which some iron-filings were added, taking care always to close the orifice with a glass stopple. The phlogisticated nitrous acid thus passed over into the receiver, and dissolved the manganese in a few hours: the solution was as limpid as water, excepting only a little fine siliceous earth. Another white precipitate, similar to that produced by adding vitriolic acid to the solution in pure nitrous acid now began to fall; but in other respects this solution agreed with the former. 1363 Manganese dissolved by phlogisticated nitrous acid.

8. An ounce of purified muriatic acid was poured upon half an ounce of levigated manganese; which, after standing about an hour, assumed a dark brown colour. A portion of it was digested with heat in an open glass vessel, and smelled like warm aqua-regia. In a quarter of an hour the smell was gone, and the solution became clear and colourless. The rest of the brown solution being digested, to see whether the muriatic acid would be saturated with manganese, an effervescence ensued, with a strong smell of aqua-regia, which lasted till next day, when the solution was found to be saturated. Another ounce of acid was poured upon the residuum, which was followed by the same phenomenon, and the manganese was entirely dissolved, a small quantity of siliceous earth only remaining. The solution, which was yellow, being now divided into two portions, some drops of vitriolic acid were poured into the one, by which it instantly became white, and a fine powder, insoluble in water, was precipitated. Some small crystals of selenite were formed by evaporation, and the residuum exhibited the same phenomenon with those abovementioned with nitrous 1364 Effects of it on spirit of salt. 1365 Entirely dissolved by this acid.

Manganeſe

trous acid, by evaporating the other half, ſome ſmall ſhining angular cryſtals were obtained, ſimilar to thoſe procured by means of the nitrous acid.

1366
Scarce ſoluble in fluor acid,

9. Very little mangaeſe was diſſolved by fluor acid, even after ſeveral days digeſtion. A great quantity was required to form a ſaturated ſolution. It had very little taſte, and gave a ſmall quantity of precipitate with fixed alkali. But if a neutral ſalt, compoſed of fluor acid and ſal ammoniac, be added, a double decompoſition takes place, and the mangaeſe is precipitated along with the fluor acid.

1367
Or in phoſphoric acid.

10. A drachm of phoſphoric acid, digeſted with as much powdered mangaeſe, diſſolved but litle of it; and, though evaporated to dryneſs, the reſiduum taſted very acid; but by adding more mangaeſe the acid was at laſt ſaturated. On adding microcoſmic ſalt to a ſolution of mangaeſe, a decompoſition takes place ſimilar to that effected by the combination of fluor acid and volatile alkali.

1368
Partly ſoluble in acid of tartar.

11. Pure acid of tartar diſſolved mangaeſe partly in the cold, and more effectually by means of heat. The whole, however, could not be diſſolved, though the acid was at laſt ſaturated by adding a great quantity of the mineral. On adding a ſolution of ſoluble tartar, a double decompoſition took place.

1369
With difficulty in the acetous.

12. Little was diſſolved by diſtilled vinegar, though boiled on mangaeſe; but after diſtilling ſpirit of verdigris ſeveral times upon it, the acid at laſt became ſaturated. The ſolution, evaporated to dryneſs, left a deliqueſcent maſs. Little or none of the remaining mangaeſe was diſſolved by concentrated vinegar, though repeatedly diſtilled upon it.

1370
Entirely diſſolved by acid of lemons;

13. With acid of lemons the whole was diſſolved with effervеſcence, excepting only ſome white earth.

1371
And by water impregnated with fixed air.

14. Water impregnated with fixed air likewiſe diſſolved mangaeſe, but parted with it on the addition of alkali, or ſpontaneouſly by expoſure to the air.

1372
Has a ſtrong attraction for phlogiſton.

From theſe experiments Mr Scheele concludes, that mangaeſe has a ſtrong elective attraction for all phlogiſtic ſubſtances; and that this attraction becomes ſtronger, if there be preſent a menſtruum which can unite with the phlogiſticated mangaeſe. Thus it attracts phlogiſton more powerfully than even the nitrous acid itſelf in the moiſt way.

1373
Becomes white by ſaturation with phlogiſton.

By ſaturation with phlogiſton, mangaeſe has the property of loſing its black colour, and aſſuming a white one, which is unuſual, the phlogiſton generally communicating a black or dark colour to the ſubſtances with which it was united.

1374
Contains ſome phlogiſton naturally.

That mangaeſe naturally contains ſome phlogiſton, though but in ſmall quantity, appears from evaporating a ſolution of it in vitriolic acid to dryneſs, and then diſtilling the maſs in a glaſs retort in an open fire. When the retort begins to melt, the acid parts fly off from the mangaeſe in a ſulphureous ſtate, leaving the former of its natural black colour. By diſtilling the maſs remaining after evaporation of the nitrous ſolution, a green volatile nitrous acid remains, and the black calx of mangaeſe remains as before.

1375
Becomes inſoluble in pure acids by loſing its phlogiſton.

A ſolution of this mineral in vitriolic or nitrous acid, precipitated by fixed alkali, retains its colour; but when calcined in the open fire, again becomes black.

By loſing its phlogiſton, mangaeſe becomes inſoluble in pure acids; and therefore the reſiduum of the abovementioned diſtillations cannot be diſſolved by adding more of the vitriolic or nitrous acids: but if that which has come over into the receiver be poured back into the retort, a ſolution will again take place by reaſon of the mangaeſe reaſſuming the phlogiſton it had parted with to the acid.

1376
Partial ſolutions of mangaeſe explained on this principle.

On this principle our author explains the reaſon of the partial ſolutions of this mineral abovementioned. Part of it is diſſolved, for inſtance, in the vitriolic acid, while the remainder is found inſoluble. This happens (ſays he), "becauſe the undiſſolved portion has parted with the little phlogiſton it naturally poſſeſſed to that portion of mangaeſe which is taken up by the vitriolic acid during the firſt digeſtion; for without that principle it is inſoluble."

Mangaeſe attracts phlogiſton more ſtrongly when combined with ſome acid than by itſelf, as appears from the following experiments.

1377
Strong attraction of mangaeſe when combined with acids for phlogiſton.

1. Levigated mangaeſe, digeſted or boiled with a ſolution of ſugar, honey, gum arabic, hartſhorn, jelly, &c. remains unchanged; but on mixing the pounded mineral with diluted vitriolic, or pure nitrous acid, and then adding ſome of theſe ſubſtances, the whole is diſſolved, the black colour vaniſhes by degrees, and the ſolution becomes as limpid as water. So ſtrong is the attraction of mangaeſe for phlogiſton in theſe circumſtances, that metals, the noble ones not excepted, render it ſoluble in theſe acids in a limpid form.

1378
Why the concentrated acid of vitriol diſſolves mangaeſe without addition.

Concentrated vitriolic acid, indeed, diſſolves mangaeſe entirely without any phlogiſton. "It would be difficult (ſays Mr Scheele) to comprehend whence the phlogiſton in this caſe ſhould come, if we were not certain that ſeveral ſubſtances, which have a great attraction for phlogiſton, can attract it in a red heat. Quickſilver and ſilver, when diſſolved in the pureſt nitrous acid, really loſe their phlogiſton, which is a conſtituent part of theſe metals. This appears from the red vapours in which the acid ariſes; and the diſſolved metallic earth cannot be again reduced to its metallic form, till it has acquired the loſt phlogiſton, which is effected either by precipitation with complete metals or by heat alone. Thus mangaeſe can attract the quantity of phlogiſton neceſſary for its ſolution by means of concentrated vitriolic acid from heat. It is not probable that the concentrated acid undergoes a decompoſition in this degree of fire; for if you ſaturate half an ounce of this acid with alkali of tartar, and afterwards calcine in a retort, with a receiver applied, an ounce and a half of powdered mangaeſe, with an equal quantity of the ſame vitriolic acid, then diſſolve the calcined maſs in diſtilled water, and likewiſe waſh well the receiver, which contains ſome drops of vitriolic acid, which are alſo to be added to the ſolution, and laſtly, add the ſame quantity of alkali, there will be no mark of ſuperabundant acid or alkali. Thence it may be concluded, that the phlogiſton in the vitriolic acid, if there really exiſts any in it, contributes nothing to the ſolution. But the mangaeſe precipitated by alkali, contains a conſiderable quantity of it; in conſequence of which it is afterwards entirely ſoluble in acids without any addition.

1379
Why the volatile ſulphureous acid diſſolves it.

"The effects of volatile ſulphureous acid on mangaeſe, clearly prove what has been aſſerted. The mangaeſe attracts the phlogiſton contained in this acid, which is the cauſe of its great volatility, and which renders

Manganeſe renders the former ſoluble in the new pure vitriolic acid. If this ſolution be mixed with concentrated vitriolic acid and diſtilled, no volatile ſulphureous acid is obtained; and if it be precipitated by means of fixed vegetable alkali, vitriolated tartar is obtained; which proves that manganeſe has a ſtronger attraction than vitriolic acid for phlogiſton in the moiſt way.

1380 Effects of nitrous acid on manganeſe explained.

"The effects of nitrous acid on this ſubſtance are ſimilar to thoſe of vitriolic acid. Could ſpirit of nitre ſuſtain as great a degree of heat as the concentrated vitriolic acid, it would alſo entirely diſſolve the manganeſe by means of the phlogiſton attracted by heat; but as this is not the caſe, it is neceſſary to add phlogiſton in the manner abovementioned. The manganeſe decompoſes phlogiſticated nitrous acid, for the ſame reaſon that it does the volatile ſulphureous acid; and that the phlogiſton of this acid really combines with manganeſe, is manifeſt from this, that the affuſion of vegetable acid produces no ſmell of aquafortis by diſplacing the phlogiſticated acid of nitre. By diſtillation with pure vitriolic acid alſo, the nitrous acid is expelled, not in a ſmoking ſtate, and of a yellow colour, but pure and colourleſs.

"In the ſolution of manganeſe by means of gum arabic or ſugar, a very conſiderable efferveſcence takes place, owing to the extrication, or probably rather the production, of fixed air from the mixture; but with phlogiſticated acid of nitre no ſuch phenomenon takes place, becauſe the manganeſe is combined with pure phlogiſton; and if this ſhould be again ſeparated, there is no cauſe for the production of fixed air. This mineral is alſo diſſolved without efferveſcence, by uniting it with nitrous acid and metals, arſenic or oil of turpentine."

1381 Exiſtence of phlogiſton in the muriatic acid proved.

As muriatic acid diſſolves manganeſe without addition, Mr Scheele is of opinion that this proves the exiſtence of phlogiſton in that acid, as has already been taken notice of. The manganeſe digeſted in the cold with ſpirit of ſalt aſſumes a dark brown colour; for it is a property of this ſubſtance that it cannot be diſſolved into a colourleſs liquor without phlogiſton, but has always a red or blue colour; but with ſpirit of ſalt the ſolution is more brown than red, on account of the fine particles of the manganeſe floating in the liquid. Here the mineral adheres but looſely to the acid, ſo that it may be precipitated by water.

1382 Explanation of the action of acid of tartar and acid of lemons.

The effects of acid of tartar and acid of lemons upon manganeſe are likewiſe explained on the principle already laid down, *viz.* the extreme attraction this ſubſtance has for phlogiſton. Thus it attracts part of that naturally contained in theſe acids, decompoſing one part of them, and being diſſolved by the other. This deſtruction of the acid is ſimilar to that of the ſugar, gum arabic, &c. which render it ſoluble in nitrous acid; for if a proper quantity of theſe are added, the manganeſe will be diſſolved, without a poſſibility of recovering the ſmalleſt particle of the vegetable ſubſtance employed; and if the ſolution be ſlowly evaporated and calcined, there will not remain the ſmalleſt mark of burned ſugar or gum. During this decompoſition, a pungent vapour ariſes, which, being collected, appears to be true vinegar. It is obtained in its pureſt ſtate from diluted vitriolic acid, ſugar, and manganeſe.

1383 Of fluor acid.

Fluor acid diſſolves but very little manganeſe, owing to its precipitating ſalt which envelopes the particles of manganeſe, and prevents the further action of the menſtruum. In all precipitations of manganeſe, however, by means of mild fixed alkalies, the full quantity is not procured; becauſe the fixed air, detached from the mineral, diſſolves part of it.

1384 Effects of manganeſe on nitre.

Though manganeſe decompounds nitre, yet this does not happen till the mixture becomes red hot. If phlogiſticated manganeſe be mixed with an equal quantity of nitre, and diſtilled in a glaſs retort, the mixture begins to grow black before the retort becomes red-hot, but no nitrous acid goes over. By lixiviation, no mark of uncombined alkali is met with; but phlogiſticated nitrous acid is extricated by the application of tamarinds, or any vegetable acid. Three parts of phlogiſticated manganeſe, mixed with one part of finely pounded nitre, yields no nitrous acid, though the nitre is alkalized as ſoon as the mixture becomes black in the retort.

1385 Experiments on manganeſe united with phlogiſton.

Mr Scheele proceeds now to another ſet of experiments upon manganeſe united with phlogiſton. In order to procure it in this ſtate, the beſt method is to diſſove in diſtilled water, and cryſtallize the ſalt obtained by ſolution of manganeſe in vitriolic acid, and then precipitate it with vegetable fixed alkali. In this ſtate it is white like chalk: but by calcination in an open fire, the ſuperfluous phlogiſton flies off, and the calx regains its uſual black colour. This change of colour likewiſe happens when the precipitation is made with cauſtic alkalies, whether fixed or volatile. The precipitate, indeed, in this caſe, is white when kept cloſe from the air, but aſſumes a brown colour when expoſed to it for any time: But when the precipitation is made by mild alkali, the white colour is preſerved by the fixed air, which in this caſe it alſo contains. By diluting the ſolution with a conſiderable quantity of water, and precipitating with cauſtic alkali, the precipitate is brown from the very beginning, owing to the air in the liquid attracting the phlogiſton from the manganeſe. The precipitate formed by lime-water is alſo brown; but on adding more of a ſtrong ſolution of manganeſe, and afterwards precipitating with cauſtic alkali, the powder falls of a white colour; becauſe the air, being already ſaturated with phlogiſton, cannot take up any more. The reſults of Mr Scheele's experiments on this phlogiſticated manganeſe are,

1386 By diſtillation *per ſe*.

1. An ounce of this ſubſtance diſtilled by itſelf in a glaſs retort, with a ſtrong fire, yielded a great quantity of fixed air with ſome drops of water. The reſiduum poured warm out of the retort grew red-hot, and ſet the paper on fire.

2. On repeating the experiment with only a drachm of phlogiſticated manganeſe, and tying a bladder to the neck of a retort, three ounce-meaſures of air came over: the reſiduum was of a light grey colour; diſſolved in acids without addition of any more phlogiſton; and took fire in that degree of heat in which ſulphur ſmokes, but does not burn. From theſe experiments, ſays Mr Scheele, it is evident, that phlogiſton does not ſeparate from manganeſe if the acceſs of air be prevented.

1387 Boiled with oil olive.

3. One part of finely powdered manganeſe boiled in four of oil-olive, effervesced violently, and diſſolved into a kind of ſalve.

1388 By diſtillation with charcoal.

4. On diſtilling a mixture of finely powdered manganeſe and charcoal, with an empty bladder tied to the mouth of the retort, a quantity of fixed air was extri-

Manganese.

cated when the retort began to melt and distended the bladder. The residuum was mostly soluble in diluted vitriolic acid.

1389 *With sulphur.*

5. On distilling half an ounce of powdered manganese with two drachms of sulphur, the latter partly rose into the neck of the retort, and some volatile acid vapours penetrated through the lute. The distillation was continued till the retort began to melt; and, on cooling, the residuum was found to weigh 5½ drachms. It was of a yellowish-grey colour; and dissolved in spirit of vitriol with effervescence, yielded an hepatic smell, some sulphur being also precipitated at the same time. By calcination in the open air, the sulphur was dissipated; but great part of the mass was rendered soluble on account of its having been penetrated by the acid vapour, and shot into crystals as though it had been formally dissolved in volatile sulphureous acid; and by repeating the calcination with more sulphur, the whole became at last entirely soluble, and was reduced to crystals.

1390 *By calcination with nitre.*

Finely powdered manganese, triturated with nitre and strongly calcined in a crucible, unites with the alkali of the nitre, while the acid is dissipated in the air. The mass formed by the union of the manganese and alkali is of a dark green colour, and soluble in water, communicating also a green colour to the liquid; but in a short time a fine yellow powder (an ochre of iron) falls to the bottom, leaving the liquor of a blue colour. By the addition of water, this solution first assumes a violet colour, grows afterwards red, and a precipitation of the manganese takes place, which resumes its natural colour as soon as it has fallen. The same precipitation takes place on the addition of a few drops of acid, or by exposure for some days to the open air. As for the dark red colour assumed by the solution when the precipitate is about to fall, Mr Scheele conjectures that the particles of manganese may naturally have a red colour, which becomes visible when the substance is dispersed through a menstruum without being perfectly dissolved.

1391 *With the addition of arsenic.*

7. By the addition of finely powdered white arsenic to the alkaline mass of nitre and manganese, the green colour disappears, and the whole becomes white; phlogisticated manganese being also precipitated on the addition of water. This arises from the more powerful attraction of manganese for the phlogiston of the arsenic than that of the arsenical acid itself; and for the same reason, if the mass be calcined with charcoal, or any other phlogistic substance, a colourless solution will be obtained.

1392 *By distillation with sal ammoniac.*

8. Half an ounce of phlogisticated manganese, distilled in a retort with an equal quantity of powdered sal ammoniac, yielded first a concrete volatile salt, after which some sal ammoniac undecomposed arose in the neck of the retort. Half an ounce of pure dephlogisticated manganese, mixed with two drachms of powdered sal ammoniac, yielded alkali in its caustic state. Both residuums were soluble in water; which shows that manganese attracts phlogiston from the volatile alkali.

1393 *By distillation with pure nitrous acid.*

9. On digesting finely powdered manganese for some weeks with pure nitrous acid and some volatile alkali, a great number of air-bubbles rise to the top, and the volatile alkali is entirely decomposed: for though the mixture be afterwards distilled in a retort with the addition of quicklime, not the least urinous smell can be perceived. This decomposition is effected by the manganese attracting the phlogiston of the volatile alkali; for that the nitrous acid has no share in this, is proved by the following experiment.

Manganese.

1394 *Volatile alkali destroyed by manganese attracting its phlogiston.*

10. An ounce of well triturated manganese was distilled with half an ounce of sal ammoniac; and a liquid alkali, such as that obtained from sal ammoniac and quicklime, was procured. On repeating this experiment, with the variation only of a bladder instead of a receiver, the same kind of air was obtained as that which rises to the top of the nitrous mixture. Though the emission of this air indicated a destruction of the volatile alkali, our author explains the reason of its being still obtained in a caustic state by the phlogiston taken from the alkali being more than sufficient to render the alkali soluble in muriatic acid; in consequence of which, the superfluous quantity combines with the manganese, and enables it to decompose the sal ammoniac in the ordinary way. It must be owned, however, that his reasoning on this subject is not entirely satisfactory, nor does the account he gives of his experiments seem entirely consistent with itself. See *Scheele's Chem. Essays*, Essay V. § xxxix.

1395 *By distillation with arsenic.*

11. Powdered manganese, distilled with an equal quantity of white arsenic, underwent no change, the arsenic flying off in its proper form; but with an equal quantity of yellow orpiment, some volatile sulphureous acid came over first, then a yellow sublimate, and at last a little red sublimate arose. On augmenting the fire by degrees, the orpiment remained obstinately attached to it. Similar effects ensued on treating manganese with an equal quantity of antimony; which likewise yielded a pungent sulphureous acid, but no sublimate. By calcination in the open air these compounds are decomposed; and the manganese, united with vitriolic acid, becomes soluble in water.

1396 *With cinnabar.*

12. On distilling manganese with an equal quantity of finely pounded cinnabar, a volatile sulphureous acid came over first; then a little cinnabar was sublimed into the neck of the retort; and at last the quicksilver, which had been the basis of the cinnabar, began to distil: the residuum, being a combination of manganese and sulphur, was similar to the compounds already described.

1397 *With corrosive sublimate.*

13. With an equal quantity of corrosive sublimate, manganese underwent no change; but when sublimed with an equal quantity of mercurius dulcis, a corrosive sublimate, and then mercurius dulcis, arose into the neck of the retort. The reason of this is, that the mercurius dulcis contains a portion of phlogiston; by being deprived of which it ceases to be mercurius dulcis, and becomes corrosive sublimate: but by reason of the strong attraction of manganese for phlogiston, the mercurius dulcis parts with that portion which is necessary to keep it in its mild state, and thus is converted into corrosive mercury.

Sect. IV. *Inflammable Substances.*

1398 *General division.*

These may be divided into the following classes: 1. Sulphurs. 2. Ardent spirits. 3. Oils and fats. 4. Resins. 6. Bitumens; and, 6. Charcoal.

§ I. SULPHURS.

1399 Sulphur. 1. *Common ſulphur.* For the extraction of this ſubſtance from its ores, ſee SULPHUR. The artificial compoſition of it we have already related, nº 715; and have now only to take notice of a very few of its properties, which come more properly under this ſection.

Sulphur, as commonly uſed in commerce and the arts, is of a pale yellow colour, of a diſagreeable and peculiar ſmell, which is rendered more ſenſible when it is heated or rubbed. By rubbing, it receives very curious electrical qualities: (See ELECTRICITY.) Its ſpecific gravity is conſiderably greater than that of water, though leſs than earths or ſtones. In cloſe veſſels, ſulphur is incapable of receiving any alteration. It melts with a very gentle heat; and then is ſublimed, adhering to the capital in ſmall, very fine, needle-like
1400 Cryſtalli-zation. cryſtals, called *flowers of ſulphur*. It may thus be ſublimed many times without alteration. If ſulphur is expoſed to a heat barely ſufficient to melt it, and very ſlowly cooled, it cryſtallizes in form of many needles croſſing one another. Some of theſe pointed cryſtals may alſo be obſerved in the interior parts of the lumps of ſulphur which have been melted, and caſt into cylyndrical moulds, as they are commonly ſold; becauſe the centre of theſe cylindrical rolls is more ſlowly cooled than the ſurface. Sulphur alſo gives this needle-like form to cinnabar, antimony, and many other minerals containing it. Sulphur may be decompoſed in ſeveral ways. The moſt ſimple is by burning; which we have already taken notice of, nº 623. It may alſo be very effectually decompoſed by mixing it with iron filings and water. In this caſe the phlogiſton is diſſipated, and the acid uniting with the iron forms a green vitriol.

1401 Decompoſed by a ſuperabundance of phlogiſton. It is very remarkable, that though ſulphur is compoſed of vitriolic acid and phlogiſton, yet the addition of more inflammable matter, ſo far from making the union ſtronger, weakens it to a great degree: and hence we have another method of decompoſing this ſubſtance; namely, by combining it with a large quantity of oil, and diſtilling the compound.

Sulphur is capable of being eaſily diſſolved in expreſſed oils, but very difficultly in eſſential ones. Theſe compoſitions are called *balſams of ſulphur;* and are ſometimes employed in medicine, but are found to be of a very heating nature. They are much uſed by farriers. According to Mr Beaumé, ſulphur cannot be diſſolved in oil, without a heat ſufficient to melt it. A larger quantity is kept diſſolved when the mixture is hot, than when cold; and conſequently the ſulphur, eſpecially if it has been diſſolved in a thin eſſential oil, cryſtallizes on cooling the mixture. The ſulphur, thus ſeparated from the oil, is found not to be altered in any reſpect from what it formerly was; but if the mixture is expoſed to a degree of heat capable of entirely decompoſing the oil, the ſulphur is decompoſed along with it, and the ſame products are obtained by diſtilling this mixture to dryneſs, as if a mixture of pure oil of vitriol and oil were diſtilled. Theſe products are, firſt a portion of oil, when an eſſential oil was made uſe of in the compoſition of the balſam; then ſome volatile ſulphureous acid, which is at firſt watery, and afterwards becomes ſtronger; along with this acid more oil ariſes, which becomes more and more thick towards the end of the diſtillation; and laſtly, when the retort has been made red hot, nothing remains but a fixed coal.

In this proceſs we find, that both the ſulphur and oil are decompoſed. The acid of the ſulphur ſeems to attack the watery principle of the oil, while its phlogiſton remains confounded with that of the oil, or is diſſipated in vapours. Hence, though the vitriolic acid in ſulphur is concentrated to the utmoſt degree, and perfectly free from water, what riſes in this diſtillation is very aqueous, by reaſon of the water which it attracts from the oil. 1402

Spirit of wine does not ſenſibly act upon ſulphur in its liquid ſtate; but if both the ſpirit of wine and ſulphur meet in the ſtate of vapour, they will then unite, and a perfect ſolution will take place. By methods of this kind, many combinations might be effected, which have been hitherto thought impoſſible. How ſoluble in ſpirit of wine. 1403

Pure ſulphur unites eaſily with all metals; gold, platina, and zinc, excepted. The compounds, except that with mercury, poſſeſs a metallic luſtre without any ductility. The ſulphur may be ſeparated by expoſing the mixture to a ſtrong fire. (See METALLURGY,) or by diſſolving the metalline part in acids. The ſulphur, however, defends ſeveral of the metals from the action of acids; ſo that this diſſolution ſucceeds but imperfectly. The reguline part of antimony is more eaſily ſeparated from ſulphur by means of acids than by any other metalline ſubſtance. Alkaline ſalts will ſeparate the ſulphur from all metals in fuſion, but they unite with it themſelves, and form a compound equally capable of diſſolving the metal. Its union with metals. 1404

Sulphur united with quickſilver forms the beautiful pigment called *cinnabar*, or *vermilion;* which is ſo much uſed in painting, that the making of it is become a diſtinct trade. Neumann relates, that in the making of cinnabar by the Dutch method, ſix or eight parts of quickſilver are made uſe of to one of ſulphur. The ſulphur is firſt melted, and then the quickſilver is ſtirred into it; upon which they unite into a black maſs. In this part of the proceſs the mixture is very apt to take fire; of which it gives notice by ſwelling up to a great degree. The veſſel muſt then be immediately covered. The maſs being beaten to powder, is afterwards to be ſublimed in large earthen jars almoſt of an equal wideneſs from end to end; theſe are hung in a furnace by a ſtrong rim of iron. When the matter is put in, the mouth of the veſſel is covered, the fire increaſed by degrees, and continued for ſeveral hours, till all the cinnabar has ſublimed; care being taken to introduce at times an iron rod to keep the middle clear; otherwiſe the cinnabar concreting there, and ſtopping up the paſſage would infallibly burſt the veſſels. Vermilion

The quantity of ſulphur directed in the common receipts for making cinnabar is greatly larger than the above; being no leſs than one-third of the quantity of quickſilver employed: accordingly it has been found, that the ſublimate, with ſuch a large quantity of ſulphur, turned out of a blackiſh colour, and required to be ſeveral times ſublimed before it became perfectly red; but we cannot help thinking, that by one gentle ſublimation

Sulphur. sublimation the superfluous sulphur might be separated, and the cinnabar become perfectly pure the second time. Hoffman gives a curious method of making cinnabar without sublimation: by shaking or digesting a little mercury with volatile tincture of sulphur, the mercury readily imbibes the sulphur from the volatile spirit, and forms with it a deep red powder, not inferior in colour to the cinnabar prepared in the common manner. Dr Lewis has found the common solutions of sulphur by alkalies, or quicklime, to have a similar effect. This cinnabar will likewise be of a darker or lighter colour, according as the solution contains more or less sulphur.

1405 Pulvis fulminans. Sulphur is a principal ingredient in gun-powder, (see GUN-POWDER.) It also enters the composition of the *pulvis fulminans*. This consists of three parts of nitre, two of the dry alkali of tartar, and one part of sulphur, well ground together. If a little quantity of this powder is laid on an iron-spoon or shovel, and slowly heated, it will explode, when it arrives at a certain degree of heat, with astonishing violence and noise. The most probable opinion concerning this is, that the fixed air contained in the alkali is, by the acid vapours acting upon and endeavouring to expel it all at once, driven off with such force, that a loud explosion is produced.

1406 Phosphorus of urine. 2. *Phosphorus of Urine*. This is a very inflammable substance, composed of phlogiston united with a certain acid, the properties of which we have already taken notice of, n° 904 *et seq.* The preparation of it was long a secret, and only perfectly discovered by Mr Margraaf, who published it in the Berlin Memoirs in 1743. This process being by far the best and most practicable, we shall content ourselves with inserting it alone.

1407 Mr Margraaf's process for making. Two pounds of sal ammonaic are to be accurately mixed with four pounds of minium, and the mixture distilled in a glass retort; by which means a very penetrating, caustic alkaline spirit will be obtained. The residuum, after the distillation, is a kind of *plumbum corneum*; n° 812. This is to be mixed with nine or ten pounds of extract of urine, evaporated to the consistence of honey. (Seventy or eighty gallons of urine are required to produce this quantity of extract.) The mixture is to be made slowly in an iron pot set over the fire, and the matter frequently stirred. Half a pound of powdered charcoal is then to be added, and the evaporation continued till the whole is reduced to a black powder. This powder is to be put into a retort, and urged with a graduated heat, till it becomes red hot, in order to expel all the volatile alkali, fetid oil, and ammoniacal salt, that may be contained in the mixture. After the distillation, a black friable residuum remains, from which the phosphorus is to be extracted by a second distillation and a stronger heat. Before it is subjected to another distillation, it may be tried by throwing some of it upon hot coals. If the matter has been well prepared, a smell of garlic exhales from it, and a blue phosphorical flame is seen undulating along the surface of the coals.

The matter is to be put into a good earthen retort, capable of sustaining a violent fire. Three quarters of the retort are to be filled with the matter which is to yield the phosphorus, and it is to be placed in a furnace capable of giving a strong heat. Mr Margraaf divides the matter among six retorts, so that if any accident happens to one, the whole matter is not lost. The retorts ought to be well luted to a receiver of a moderate size, pierced with a small hole, and half full of water; and a small wall of bricks must be raised between the furnace and receiver, in order to guard this vessel against heat as much as possible. The retorts are to be heated by slow degrees for an hour and an half; then the heat is to be increased till the vessels are red hot, when the phosphorus ascends in luminous vapours. When the retort is heated till between a red and white, the phosphorus passes in drops, which fall and congeal in the water at the bottom of the receiver. This degree of heat is to be continued till no more comes over. When a retort contains eight pints or more, this operation continues about five hours.

In the first distillation, phosphorus never passes pure, but is always of a blackish colour, by reason of its carrying along with it some part of the coal. From this, however, it may be purified by rectification in a small glass-retort, to which is luted a receiver half full of water. A very gentle heat is sufficient; because phosphorus, once formed, is very volatile; and as the fuliginous matter was raised probably by the fixed air emitted by the charcoal in the instant of its union with the phosphorine acid, none of it can arise in a second distillation. 1408 Rectification of phosphorus.

The phosphorus is then to be divided into small cylindrical rolls, which is done by putting it in glass-tubes immersed in warm water; for the phosphorus is almost as fusible as suet. It takes the form of the glass-tubes; from which it may be taken out, when it is cold and hardened. This must be done under water, least the phosphorus should take fire.

This concrete continually appears luminous in a dark place; and by a very slight heat takes fire, and burns far more vehemently than any other known substance. Hence it is necessary to be very cautious in the distillation of it; for if the receiver should happen to break while the phosphorus is distilling, and a little flaming phosphorus fall upon the operator's legs or hands, it would burn its way to the bone in less than three minutes. In this case, according to Mr Hellôt, nothing but urine will stop its progress. 1409 Process sometimes dangerous.

Though phosphorus takes fire very readily by itself, it does not inflame at all by grinding it with other inflammable bodies, as camphor, gun-powder, or essential oils. In grinding it with nitre, some luminous flashes are observed; but the mixture never burns, unless the quantity of phosphorus be large in proportion to the nitre: rubbed pretty hard on a piece of paper or linen, it sets them on fire if they are rough, but not if they are smooth. It fires written paper more readily than such as is white, probably from the former having more asperities. On grinding with iron-filings, it presently takes fire.

Oils ground with phosphorus appear, like itself, luminous in a temperately warm place; and thus become a liquid phosphorus, which may be rubbed on the hands, &c. without danger. Liquid phosphorus is commonly prepared by grinding a little of the solid phosphorus with oil of cloves, or rubbing it first with camphor, and this mixture with the oil. A luminous *amalgam*, as it is called, may be obtained, by digesting a scru- 1410 Liquid phosphorus.

Sulphur. a scruple of solid phosphorus with half an ounce of oil of lavender, and, when the phosphorus begins to dissolve and the liquor to boil, adding a drachm of pure quicksilver; then briskly shaking the glass for five or six minutes till they unite.

1411 Experiments on phosphorus with spirit of wine. Rectified spirit of wine, digested on phosphorus, extracts a part of it, so as to emit luminous flashes on being dropt into water. It is computed that one part of phosphorus will communicate this property to 600,000 parts of spirit. The liquor is never observed to become luminous of itself, nor in any other circumstance except that abovementioned. By digestion for some months, the undissolved phosphorus is reduced to a transparent oil, which neither emits light nor concretes in the cold. By washing with water, it is in some measure revived; acquiring a thicker consistence, and becoming again luminous, though in a less degree than at first. During this digestion, the glass is very apt to burst.

1412 With essential oils and acids. Phosphorus is partially dissolved by expressed oils; and totally, or almost so, in essential oils and ether. When essential oils are saturated with it by heat, a part of the phosphorus separates, on standing in the cold, in a crystallize form. Concentrated spirit of salt has no action on it. In distillation, the spirit rises first, and the phosphorus after it unchanged. Spirit of nitre dissolves it, and the dissolution is attended with great heat and copious red fumes; so that great part of the spirit distils without the application of any external heat, and the phosphorus at last takes fire, explodes, and bursts the vessels. Oil of vitriol likewise dissolves phosphorus, but not without a heat sufficient to make the acid distil. The distilled liquor is white, thick, and turbid; the residuum is a whitish tenacious mass, which deliquates, but not totally, in the air. Phosphorus itself is resolved into an acid liquor on being exposed two or three weeks to the air, its inflammable principle seeming by degrees to be dissipated.

Phosphorus has been reported to produce extraordinary effects in the resolution of metallic bodies: but from the experiments that have been made with this view, it does not appear to have any remarkable action on them; at least on the precious ones, gold and silver, for the resolution or subtilization of which it has been chiefly recommended. The following experiments were made by Mr Margraaf.

1413 Mr Margraf's experiments with metals. 1. A scruple of filings of gold were digested with a drachm of phosphorus for a month, and then committed to distillation. Part of the phosphorus arose, and part remained above the gold, in appearance resembling glass: this grew moist on the admission of air, and dissolved in water, leaving the gold unaltered. Half a drachm of fine silver, precipitated by copper, being digested with a drachm of phosphorus for three hours, and the fire then increased to distillation, greatest part of the phosphorus arose pure, and the silver remained unchanged. Copper filings being treated in the same manner, and with the same quantity of phosphorus, the phosphorus sublimed as before; but the remaining copper was found to have lost its metallic brightness, and to take fire on the contact of flame. Iron filings suffered no change. Tin filings run into granules, which appeared to be perfect tin. Filings of lead did the same. The red calx of mercury, called *precipitate per se*, treated in the same manner, was totally converted into running quicksilver. 2. Regulus of antimony suffered no change itself, but occasioned a change in the consistence of the phosphorus; which, after being distilled from this semimetal, refused to congeal, and continued, under water, fluid like oil-olive. With bismuth there was no alteration. A drachm of phosphorus being distilled and cohobated with an equal quantity of zinc, greatest part of the zinc sublimed in form of very light pointed flowers of a reddish-yellow colour: these flowers, injected into a red hot crucible, took fire, and run into a glass resembling that of borax. White arsenic, sublimed with phosphorus, arose along with it in form of a mixed red sublimate. Sulphur readily unites with phosphorus into a mass which smells like *hepar sulphuris*. This does not easily take fire on being rubbed; but exposed to a moderate dry heat, it flames violently, and emits a strong sulphureous fume. If phosphorus is burnt in an open vessel, a quantity of acid remains behind; and if a glass bell is held over it, an acid likewise sublimes in the form of white flowers.

3. *Mr Canton's phosphorus.* This is a composition of quicklime and common sulphur. The receipt for making it is as follows. "Calcine some common oyster-shells, by keeping them in a good coal-fire for half an hour; let the purest part of the calx be pulverized and sifted. Mix with three parts of this powder one part of flowers of sulphur. Let this mixture be rammed into a crucible of about an inch and a half in depth till it be almost full; and let it be placed in the middle of the fire, where it must be kept red hot for an hour at least, and then set by to cool: when cold, turn it out of the crucible; and cutting or breaking it to pieces, scrape off, upon trial, the brightest parts; which, if good phosphorus, will be a white powder. This kind of phosphorus shines on being exposed to the light of the sun, or on receiving an electrical stroke. 1414 Mr Canton's phosphorus.

4. *Phosphorus of Homberg.* This substance, which has the singular property of kindling spontaneously when exposed to the air, was accidentally discovered by Mr Homberg, as he was endeavouring to distil a clear flavourless oil from human excrements. Having mixed the excrement with alum, and distilled over as much as he could with a red heat, he was much surprised at seeing the matters left in the retort take fire upon being exposed to the air, some days after the distillation was over. This induced him to repeat the operation, in which he met with the same success; and he then published a process, wherein he recommended alum and human excrement for the preparation of the phosphorus. Since his time, however, the process has been much improved; and it is discovered, that almost every vitriolic salt may be substituted for the alum, and most other inflammable substances for the excrement; but though alum is not absolutely necessary for the success, it is one of the vitriolic salts that succeed best. The following process is recommended in the Chemical Dictionary. 1415 Homberg's phosphorus or pyrophorus.

Let three parts of alum and one of sugar be mixed together. This mixture must be dried in an iron shovel, over a moderate fire, till it be almost reduced to a blackish powder or coal; during which time it must be stirred with an iron spatula. Any large masses must 1416 Best method of preparing.

be

be bruised into powder; and then it must be put into a glass matrass, the mouth of which is rather strait than wide, and seven or eight inches long. This matrass is to be placed in a crucible, or other earthen vessel, large enough to contain the belly of the matrass, with about a space equal to that of a finger all round it. This space is to be filled with sand, so that the matrass shall not touch the earthen vessel. The apparatus is then to be put into a furnace, and the whole to be made red hot. The fire must be applied gradually, that any oily or fuliginous matter may be expelled; after which, when the matrass is made red hot, sulphureous vapours exhale: this degree of heat is to be continued till a truly sulphureous flame, which appears at the end of the operation, has been seen nearly a quarter of an hour: the fire is then to be extinguished, and the matrass left to cool, without taking it out of the crucible; when it ceases to be red hot, it must be stopped with a cork. Before the matrass is perfectly cold, it must be taken out of the crucible, and the powder it contains poured as quickly as possible into a very dry glass phial, with a glass stopper. If we would preserve this phosphorus a long time, the bottle containing it must be opened as seldom as possible. Sometimes it kindles while it is pouring into the glass phial; but it may be then extinguished by closing the phial expeditiously. A small quantity of this pyrophorus laid on paper, and exposed to the air, immediately takes fire, becomes red like burning coals, and emits a strong sulphureous vapour greatly resembling that which arises on decomposing liver of sulphur.

1417 Is not injured by mere exposure to light.

It has been generally alleged, that the common black phosphorus is impaired by being exposed to the light; but Mr Cavallo has discovered the fallacy of this supposition by the following experiment. Some portions of the same pyrophorus were inclosed in three glass tubes, and immediately sealed up hermetically. On the 22th of May 1779, two of them were suspended from a nail out of a window, and the third was wrapped up in paper and inclosed in a box, where not the least glimmering of light could enter. In this situation they were left for more than a year; after which one of those that had been kept out of the window was broke, along with that which had been kept in the dark, in the presence of Mr Kirwan; when the pyrophorus seemed to be equally good in each tube, taking fire in about half a minute after it was taken out of the tubes, and exposed to the air on a piece of paper.

1418 Cause of the accension.

There are many different kinds of pyrophori: some of the most remarkable of which are described under the article PYROPHORUS. Many theories have been invented to solve the phenomenon of their accension on the contact of air. This has been thought owing to the conversion of the earth of alum into lime, or to a remainder of the vitriolic acid attracting moisture from the atmosphere; but the formation of pyrophorus without either alum or vitriolic acid, shows that neither of these opinions can be just. It is more probable, therefore, that, the heat is occasioned by the total dissipation of that aqueous part which is essential to the constitution of terrestrial substances. In consequence of this, the water contained in the atmosphere is not only attracted with avidity, but decompounded by the matter reduced to such a state of extreme dryness. By these operations it gives out the latent heat contained in it, and this produces the accension in question.

§ 2. *Ardent Spirits.*

See FERMENTATION and DISTILLATION.

§ 3. *Oils.*

1419 Essential oils.

1. *Essential Oils.* Those oils are called *essential* which have evidently the smell of the vegetable from which they are drawn. For the method of procuring them, see DISTILLATION. They are distinguished from all others by their superior volatility, which is so great as to cause them rise with the heat of boiling water. All these have a strong aromatic smell, and an acrid, caustic taste; in which respect also they differ from other oils.

1420 Supposed cause of their taste.

This taste is thought to proceed from a copious and disengaged acid, with which they are all penetrated. The presence of this disengaged acid in essential oils, appears from the impression they make upon the corks of bottles in which they are kept. These corks are always stained of a yellow colour, and a little corroded, nearly as they are by nitrous acid. The vapour of these oils also reddens blue paper, and converts alkalies into neutral salts.

1421 Of their solubility in spirit of wine.

This acid is likewise supposed to be the cause of their solubility in spirit of wine. They are not all equally soluble in this menstruum, because they do not all contain an equal quantity of acid. As this acid is much disengaged, they lose a great deal of it by repeated distillations, and therefore they become less and less soluble on being frequently distilled. By evaporation they lose their most volatile and thin part, in which the specific smell of the vegetable from which they are extracted resides; by which loss they become thick, and acquire the smell and consistence of turpentine, and even of resins. In this state they are no longer volatile with the heat of boiling water; and, if distilled with a stronger fire, they give over an oil which has neither smell nor taste of the vegetable whence they were extracted, but is entirely empyreumatic, and similar to those oils procured by distilling vegetable or animal substances with a strong fire. See DISTILLATION.

1422 Camphor.

To the class of essential oils, the volatile concrete called *camphor* seems most properly to belong. With them it agrees in its properties of inflammability, solubility in spirit of wine, and a strong aromatic flavour. The only differences between them are, that camphor is always in a solid state, and is incapable of decomposition by any number of sublimations.

1423 Decomposed by distillation with bole.

It has, however, been found possible to decompose it by distillation with certain additions. By distilling it several times along with bole, we obtain a fluid having the properties of an essential oil, soluble in water, and separating again on the the addition of spirit of wine.

1424 With dephlogisticated nitrous acid.

On distilling it eight times with dephlogisticated nitrous acid, we obtain a salt having the form of a parallelopiped, of an acid and bitter taste, and changing the juice of violets and turnsole red. This has the properties of a true acid; combines with fixed and volatile alkalies into neutral salts capable of being crystallized; dissolves copper, iron, bismuth, arsenic, and cobalt.

Oils.

cobalt. With magnesia it forms regular crystals, in some measure resembling basaltes. It is distinguished from the acid of sugar by not precipitating lime from its solution in marine acid, and by forming with magnesia a white powder soluble in water.

According to Neumann, all the camphor made use of is the produce of two species of trees; the one growing in Sumatra and Borneo, the other in Japan. Of these, the Japan kind is the only one brought into Europe. The tree is about the size of a large lime, the flowers white, and the fruit a small red berry. All parts of the tree are impregnated with camphor; but the roots contain most, and therefore are chiefly made use of for the preparation of this commodity: though, in want of them, the wood and leaves are sometimes mixed.

The camphor is extracted by distillation with water in large iron pots filled with earthen heads stuffed with straw; greatest part of the camphor concretes among the straw, but passes down into the receiver among the water. In this state it is found in small bits like gray salt-petre, or common bay-salt; and requires to be purified either by a second sublimation, or by dissolution in spirit of wine, filtration, and exsiccation. If the first method is followed, there will be some difficulty in giving it the form of a perfect transparent cake. A difficulty of this kind indeed always occurs in sublimations; and the only way is to keep the upper part of the glass to such a degree of heat as may keep the sublimate in a half-melted state. Dr Lewis recommends the depuration of camphor by spirit of wine, and then melting it into a cake in the bottom of a glass.

Camphor possesses considerable antisceptic virtues; and is a good diaphoretic, without heating the constitution; with which intention it is often used in medicine. It is likewise employed in fire-works and several other arts, particularly in making varnishes. See VARNISH.

1425 Soluble in ardent spirits and oil. This substance dissolves easily and plentifully in vinous spirits and in oils; four ounces of spirit of wine will dissolve three of camphor. On distilling the mixture, the spirit rises first, very little camphor coming over with it. This shows that camphor, however volatile it may seem by its smell, is very far from having the volatility of ether, and consequently is improperly classed with substances of that kind.

1426 Empyreumatic oils. 2. *Empyreumatic Oils.* Under this name are comprehended all those oils, from whatever substance obtained, which require a greater heat for their distillation than that of boiling water. These are partially soluble in spirit of wine, and becomes more and more so by repeated distillations. The empyreumatic oils obtained from animal substances are at first more fetid than those procured from vegetables; but by repeated distillations, they become exceedingly attenuated and volatile, becoming almost as white, thin, and volatile, as ether. They then acquire a property of acting upon the brain and nervous system, and of allaying its irregular movements, which is common to them with all other inflammable matters when highly attenuated and very volatile; but this kind of oil is particularly recommended in epileptic and convulsive affections. It is given from 4 to 10 or 11 drops: but, though prepared with the utmost care, it is very susceptible of losing its whiteness, and even its thinness, by a short exposure to air; which proceeds from the almost instantaneous evaporation of its more thin and volatile parts, and from the property which the less volatile remainder has of acquiring colour. To avoid this inconvenience, it must be put, as soon as it is made, into very clean glass bottles with glass stoppers, and exposed to the air as little as possible.

The most important observations concerning the method of making the pure animal oils are, first to change the vessel at each distillation, or at least to make them perfectly clean; for a very small quantity of the thicker and less volatile part is sufficient to spoil a large quantity of that which is more rectified. In the second place, Mr Beaumé has observed, that this operation may be greatly abridged, by taking care to receive none but the most volatile part in each distillation, and to leave a large residuum, which is to be neglected, and only the more volatile part to be further rectified. By this method a considerable quantity of fine oil may be obtained at three or four distillations, which could not otherwise be obtained at fifty or fixty. 1427 How rectified.

3. *Animal Fats.* Though these differ considerably from one another in their external appearance, and probably in their medicinal qualities, they afford, on a chemical analysis, products similar in quality, and differing but inconsiderably in quantity. They all yield a larger portion of oil, and no volatile salt; in which respect they differ from all other animal substances. Two ounces of hogs's lard yielded, according to Neumann, two drachms of an empyreumatic liquor, and one ounce five drachms and 50 grains of a clear brown-coloured oil of a volatile smell, somewhat like horse-radish. The *caput mortuum* was of a shining black colour, and weighed 10 grains. 1428 Animal fats.

Tallow being distilled in the same manner, two drachms of empyreumatic liquor were obtained from two ounces of it; of a clear brown oil, smelling like horse-radish, one ounce six drachms and 12 grains. The remaining coal was of a shining black colour, and weighed 18 grains. A particular kind of acid is now found to be contained in it. 1429 Tallow.

The marrow of bones differs a little from fats, when chemically examined. Four ounces of fresh marrow, distilled in the usual manner, gave over three drachms and a scruple of a liquor which smelled like tallow; two scruples and an half of liquor which had more of an empyreumatic and a sourish smell; two ounces and an half of a yellowish-brown, butyraceous oil, which smelled like horse-radish; and six drachms and an half of a blackish-brown oil of the same smell. The *caput mortuum* weighed four scruples. 1430 Marrow.

All animal fats, when perfectly pure, burn totally away without leaving any feces, and have no particular smell. In the state in which we commonly find them, however, they are exceedingly apt to turn rancid, and emit a most disagreeable and noxious smell; and to this they are peculiarly liable, when long kept in a gentle degree of heat. In this state, too, an inflammable vapour arises from them, which when on fire is capable of producing explosions. Hence, in those works where large bellows are used, they have been often suddenly burst by the inflammable vapours arising from the rancid oil employed for softening the leather 1431 Rancid oils purified.

Resins and Balsams. leather. The expressed unctuous oils of vegetables are subject to the same changes; but from this rancidity they may all be freed most effectually, by the simple process of agitating them well with water: which is to be drawn off, and fresh quantities added, till it comes off at last clear and insipid, without any ill smell. The proper instrument for performing this operation in large is a barrel-churn, having in it four rows of narrow split deals, from the centre to the circumference, each piece set at obtuse angles to the other, in order to give different directions to the oil and water as the churn turns round, thereby to mix them more intimately. The churn is to be swiftly turned round for a few minutes; and must then be left at rest, till the oil and water have fully separated; which will be in 15 or 20 minutes, more or less, according to the size of the churn. When this water is drawn off, fresh water is to be put in, and the churn again turned round, and this continued till the oil is perfectly sweet. If the oil and water are allowed to stand together for some days, a gelatinous substance is found between them, which is not very easily miscible either with oil or water. Chalk, quicklime, and alkaline salts, are found also capable of taking off the rancidity from oils and fats; but have the inconvenience of destroying a part of their substance.

§ 4. *Resins and Balsams.*

These are commonly reckoned to be composed of an essential oil thickened by an acid; as the essential oils themselves are found to be convertible into a similar substance, by the exhalation of their more volatile parts. True resins are generally transparent in a considerable degree, soluble in spirit of wine, and possessed of a considerable degree of flavour.

1432 Whence procured. Resins are originally produced by inspissating the natural juices which flow from incisions made in the stems of growing vegetables, and are in that state called *balsams*. The balsams may be considered as essential oils thickened by losing some of their odoriferous principle, and of their finest and most volatile parts. There are several kinds of balsams, which, however, differ from each other only in the smell and degree of consistence; and therefore all yield similar products on distillation. An analysis of turpentine therefore will be sufficient as an example of the analysis and natural properties of all the rest.

1433 Turpentine Chio. The true turpentine-tree is found in Spain and the southern parts of France, as well as in the island of Chio and in the Indies. It is a middling-sized evergreen-tree, with leaves like those of the bay, bearing purplish, imperfect flowers; and on separate pedicles hard unctuous berries like those of juniper. It is extremely resinous; and unless the resin is discharged, decays, produces fungous excrescences, swells, bursts, and dies; the prevention of which consists wholly in plentiful bleeding, both in the trunk and branches. The juice is the *Chio* or *Cyprus turpentine* of the shops. This sort is quite of a thick consistence, of a greenish white colour, clear and transparent, and of scarcely any taste or smell.

1434 Venice. The kind now called *Venice turpentine*, is no other than a mixture of eight parts of common yellow or black rosin with five parts of oil of turpentine. What was originally Venice turpentine is now unknown. Neumann relates, that the Venice turpentine sold in his country was no other than that prepared from the larix tree, which grows plentifully in some parts of France, as also in Austria, Tyrol, Italy, Spain, &c. Of this there are two kinds; the young trees yielding a thin limpid juice, resembling balsam of copaiba; the older, a yellower and thicker one. 1435

The *Strasburg turpentine* is extracted from the silver-fir. Dr Lewis takes notice that some of the exotic firs afford balsams, or resins, superior to those obtained from the native European ones; as particularly that called *balm of Gilead fir*, which is now naturalized to our own climate. A large quantity of an elegant resinous juice may be collected from the cones of this tree: the leaves also, when rubbed, emit a fragrant smell; and yield, with rectified spirit, an agreeable resinous extract. 1436 Strasburg.

The common turpentine is prepared from different sorts of the pine; and is quite thick, white, and opaque. Even this is often counterfeited by mixtures of rosin and common expressed oils. 1437 Common.

All the turpentines yield a considerable proportion of essential oil. From sixteen ounces of Venice turpentine, Neumann obtained, by distillation with water, four ounces and three drachms of oil. The same quantity distilled, without addition, in the heat of a water-bath, gave but two ounces and an half; and from the residuum treated with water, only an ounce could be obtained, The water remaining in the still is found to have imbibed nothing from the turpentine; on the contrary, the turpentine is found to imbibe part of the water; the residuum and the oil amounting to a full ounce on the pound more than the turpentine employed. When turpentine is distilled or boiled with water till it becomes solid, it appears yellowish; when the process is further continued, of a reddish brown colour: in the first state, it is called *boiled turpentine*; and in the latter, *colophony*, or *rosin*. Phenomena on distillation.

On distilling sixteen ounces of turpentine in a retort with an open fire, increased by degrees, we obtain first four ounces of a limpid colourless oil; then two ounces and two drachms of a yellowish one; four ounces and three drachms of a thicker yellow oil; and two ounces and one drachm of a dark brownish red empyreumatic oil, of the consistence of balsam, and commonly called *balsam of turpentine*. 1438

The limpid essential oil called *spirit of turpentine*, is exceedingly difficult of solution in spirit of wine; tho' turpentine itself dissolves with great ease. One part of the oil may indeed be dissolved in seven parts of rectified spirit; but on standing for some time, the greatest part of the oil subsides to the bottom, a much greater proportion of spirit being requisite to keep it dissolved. 1439 Essential oil difficult of solution.

2. *Benzoin*. This is a very brittle brownish resin, of an exceedingly fragrant smell. The tree which produces benzoin is a native of the East Indies; particularly of Siam and the island of Sumatra. It is never permitted to exceed the sixth year; being, after this time, unfit for producing the benzoin. It is then cut down, and its place supplied by a young tree raised commonly from the fruit. One tree does not yield above three pounds of benzoin. Benzoin.

A tree supposed to be the same with that which affords

Bitumens. fords benzoin in the East Indies, is plentiful also in Virgina and Carolina; from whence it has been brought into England, where it grows with vigour in the open ground. The bark and the leaves have the smell of benzion; and yield with rectified spirit a resin of the same smell; but no resin has been observed to issue from it naturally in England, nor has any benzoin been collected from it in America.

1440 Soluble in spirit of wine. Benzoin dissolves totally in spirit of wine into a blood-red liquor, leaving only the impurities, which commonly amount to no more than a scruple on an ounce. To water, it gives out a portion of saline matter of a peculiar kind, volatile and sublimable in the fire. See 984 *et seq*.

The principal use of resins is in the making of lacquers, varnishes, &c. See VARNISH.

§ 5. *BITUMENS*.

THESE are inflammable mineral bodies, not sulphureous, or only casually impregnated with sulphur. They are of various degrees of consistency; and seem, in the mineral kingdom, to correspond with the oils and resins in the vegetable.

1441 Origin of bitumens. Concerning the origin of bitumens, chemists are not at all agreed. Some chemical writers, particularly Mr Macquer, imagine bitumens to be no other than vegetable resins altered in a peculiar manner by the admixture of some of the mineral acids in the earth; but Dr Lewis is of a contrary opinion, for the following reasons.

"Mineral bitumens are very different in their qualities from vegetable resins; and, in the mineral kingdom, we find a fluid oil very different from vegetable oils. The mineral oil is changed by mineral acids into a substance greatly resembling bitumens; and the vegetable oils are changed by the same acids into substances greatly resembling the natural resins.

"From bitumens we obtain, by distillation, the mineral oil, and from resins the vegetable oil, distinct in their qualities as at first. Vegetable oils and resins have been treated with all the known mineral acids; but have never yielded any thing similar to the mineral bitumens. It seems, therefore, as if the oily products of the two kingdoms were essentially and specifically different. The laws of chemical inquiries at least demand, that we do not look upon them any otherwise, till we are able to produce from one a substance similar to the other. When this shall be done, and not before, the presumption that nature effects the same changes in the bowels of the earth, will be of some weight."

1442 Naphtha. There is a perfectly fluid, thin bitumen, or mineral oil, called *naphtha*, clear and colourless as crystal; of a strong smell; extremely subtile; so light as to swim on all known liquors, ether perhaps excepted: spreading to a vast surface on water, and exhibiting rainbow colours; highly inflammable: formerly made use of in the composition of the supposed inextinguishable greek fire.

1443 Petroleum. Next to this in consistence is the *oleum petra*, or *petroleum*; which is grosser and thicker than naphtha, of a yellowish, reddish, or brownish colour; but very light, so as to swim even on spirit of wine. By distillation, the petroleum becomes thinner and more subtile, a gross matter being left behind; it does not, however, easily arise, nor does it totally lose its colour by this process, without particular managements or additions. Bitumens.

Both naphtha and petroleum are found plentifully in some parts of Persia, trickling through rocks or swimming on the surface of waters. Kempfer gives an account of two springs near Baku; one affording naphtha, which it receives in drops from subterraneous veins; the other, a blackish and more fetid petroleum, which comes from Mount Caucasus. The naphtha is collected for making varnishes; the petroleum is collected in pits, and sent to different places for lamps and torches.

Native petrolea are likewise found in many different places, but are not to be had in the shops; what is sold there for petroleum, being generally oil of turpentine coloured with alkanet root. The true naphtha is recommended against disorders of the nerves, pains, cramps, and contractions of the limbs, &c. but genuine naphtha is rarely or never brought to this country.

There are some bitumens, such as amber, ambergris, pit-coal, and jet, perfectly solid; others, such as Barbadoes tar, of a middle consistence between fluid and solid. Turf and peat are likewise thought to belong to this class.

1. *Amber*. This substance melts, and burns in the fire, emitting a strong peculiar smell. Distilled in a strong heat, it yields a phlegm, an oil, and a particular species of acid salt. The distillation is performed in earthen or glass retorts, frequently with the addition of sand, sea-salt, coals, &c. which may break the tenacity of the melted mass, so as to keep it from swelling up, which it is apt to do by itself. These additions, however, make a perceptible difference in the produce of the distillation: with some the salt proves yellowish and dry; with others, brownish or blackish, and unctuous or soft like an extract: with some, the oil is throughout of a dark brown colour; with others, it proves externally green or greenish; with elixated ashes, in particular, it is of a fine green. The quantity of oil and phlegm is greatest when coals are used, and that of salt when sea-salt is used. 1444 Amber.

The most advantageous method of distilling amber, however, is without any addition; and this is the method used in Prussia, where the greatest quantities of salt and oil of amber are made. At first a phlegmatic liquor distils; then a fluid oil; afterwards one that is thick and more ponderous; and last of all, an oil still more ponderous along with the salt. In order to collect the salt more perfectly, the receiver is frequently changed; and the phlegm, and light oil, which arise at first, are kept by themselves. The salt is purified, by being kept some time on bibulous paper, which absorbs a part of the oil: and changing the paper as long as it receives any oily stain. For the further depuration as well as the nature of this salt, see SUCCINUM. 1445 Most advantageously distilled without addition.

2, *Ambergris*. This concrete, which is only used as a perfume, yields, on distillation, products of a similar nature to that of amber, excepting that the volatile salt is in much less quantity. See AMBERGRIS. 1446 Ambergris.

3. *Pit-coal*. See the articles COAL and LITHANTHRAX 1447 Pit-coal.

Bitumens. THRAX. This substance yields by distillation, according to the translator of the Chemical Dictionary, 1. phlegm, or water; 2. a very acid liquor; 3. a thin oil, like naphtha; 4. a thicker oil, resembling petroleum, which falls to the bottom of the former, and which rises with a violent fire; 5. an acid, concrete salt; 6. *an uninflammable earth* (we suppose he means a piece of charred coal, or cinder) remains in the retort. The fluid oil obtained from coals is said to be exceedingly inflammable, so as to burn upon the surface of water like naphtha itself.

1448 Peat. 4. *Peat.* There are very considerable differences in this substance, proceeding probably from the admixture of different minerals: for the substance of peat is plainly of vegetable origin; whence it is found to answer for the smelting of ores, and the reduction of metallic calces, nearly in the same manner as coals of wood. Some sorts yield, in burning, a very disagreeable smell, which extends to a great distance; whilst others are inoffensive. Some burn into grey or white, and others into red, ferruginous ashes. The ashes yield, on elixation, a small quantity of alkaline, and some neutral salts.

1449 Phenomena on distillation. The smoke of peat does not preserve or harden flesh like that of wood; and the soot into which it condenses is more apt to liquefy in moist weather. On distilling peat in close vessels, there arises a clear insipid phlegm; an acid liquor, which is succeeded by an alkaline one; and a dark-coloured oil. The oil has a very pungent taste, and an empyreumatic smell; less fetid than that of animal substances, but more so than that of mineral bitumens. It congeals, in the cold, into a pitchy mass, which liquefies in a small heat: it readily catches fire from a candle; but burns less vehemently than other oils, and immediately goes out upon removing the external flame. It dissolves almost totally in rectified spirit of wine, into a dark, brownish-red liquor.

§ 6. CHARCOAL.

1450 Differences between the coals of different substances. THIS is the form to which all inflammable matters are reducible, by being subjected to the most vehement action of fire in close vessels; but though all the coals are nearly similar to one another in appearance, there is nevertheless a very considerable difference among them as to their qualities. Thus the charcoal of vegetables parts with its phlogiston very readily, and is easily reducible to white ashes: charred pit-coal, or, as it is commonly called, *coak*, much more difficultly; and the coals of burnt animal substances, far more difficultly than either of the two. Mr Macquer acquaints us, that the coal of bullock's blood parts with its phlogiston with the utmost difficulty. He kept it very red, in a shallow crucible surrounded with charcoal, for six hours and more, stirring it constantly that it might be all exposed to the air, without being able to reduce it to white, or even grey ashes. It still remained very black, and full of phlogiston. The coals of pure oils, or concrete oily substances, and soot, which is a kind of coal raised during the inflammation of oils, are as difficultly burnt as animal coals. These coals contain very little saline matter, and their ashes furnish no alkali. These coals, which are so difficultly burnt, are also less capable of inflaming with nitre than others more combustible; and some of them, in a great measure, resist even the action of nitre itself.

1451 Charcoal perfectly refractory. Charcoal is the most refractory substance in nature; no instance having been known of its ever being melted, or showing the least disposition to fusion, either by itself, or with additions: hence, charcoal is found to be the most proper support for such bodies as are to be exposed to the focus of a large burning glass. The only true solvent of charcoal is *hepar sulphuris*. By the violent heat of a burning-glass, however, it is found to be entirely dissipable into inflammable air, without having any residuum. See AEROLOGY, n° 129. and CHARCOAL.

The different substances mixed with different coals, render some kinds of charcoal much less fit to be used in reviving metals from their calces, or in smelting them originally from their ores. The coals of vegetable substances are found to answer best for this purpose. See METALLURGY.

SECT. V. *Vegetable and Animal Substances.*

Vegetable and animal substances. THE only substances afforded by vegetables or animals, which we have not yet examined, are the mucilaginous, or gummy; and the colouring parts obtained by infusion, or boiling in water; and the calculous concretions found in the bodies of animals, chiefly in the human bladder. The colouring matter is treated of under the article *COLOUR-Making*, to which we refer; and in this section shall only consider the nature of the others.

§ 1. *MUCILAGE or GUM.*

1452 Mucilage. THE mucilage of vegetables is a clear transparent substance, which has little or no taste or smell, the consistence of which is thick, ropy, and tenacious, when united with a certain quantity of superabundant water. It is entirely and intimately soluble in water, and contains no disengaged acid or alkali.

When mucilage is dissolved in a large quantity of water, it does not sensibly alter the consistence of the liquor: but, by evaporation, the water grows more and more thick; and, at last, the matter acquires the consistence of gum arabic, or glue; and this without losing its transparency, provided a heat not exceeding that of boiling water has been used.

1453 Phenomena on distillation. Gums, and solid mucilages, when well dried and very hard, are not liquefied in the fire like resins, but swell, and emit many fumes; which are, at first, watery: then oily, fuliginous, and acrid. Distilled in close vessels, an aqueous acid liquor comes over along with an empyreumatic oil, as from other vegetable substances; a considerable quantity of coal remains, which burns to ashes with difficulty.

Mucilages and gums are not soluble either by oils, spirit of wine, alkalies, or acids, except in so far as they dissolve in these liquors by means of the water in which the alkali or acid are dissolved. They are, however, the most effectual means of uniting oil with water. Three parts of mucilage, poured upon one part of oil, will incorporate with it by trituration or agitation; and the compound will be soluble in water. Vegetable gums are used in medicine, as well as the mechanic arts; but the particular uses to which each of them is applicable, will be mentioned under the name of each particular gum.

Calculus.

1454 Jelly and glue.

The mucilage obtained from animal fubftances, when not too thick, is called *jelly*, or *gelatinous matter*; when further infpiffated, the matter becomes quite folid in the cold, and is called *glue*. If the evaporation is ftill further continued, the matter acquires the confiftence of horn.

This gelatinous fubftance feems to be the only true animal one; for all parts of the body, by long continued boiling, are reducible to a jelly, the hardeft bones not excepted. Animal jelly, as well as vegetable mucilage, is almoft infipid and inodorous; but, though it is difficult to defcribe the difference betwixt them when apart, it is very eafily perceived when they are both together. Acids and alkalies, particularly the latter, diffolve animal jellies with great eafe; but the nature of thefe combinations is not yet underftood. The other properties of this fubftance are common to it with the vegetable gums, except only that the animal mucilage forms a much ftronger cement than any vegetable gum: and is therefore much employed for mechanical purpofes, under the name of *glue*. See Glue and Isinglass.

§ 2. *Of the* Human Calculus.

1455 Scheele's experiments on the human calculus.

This fubftance has been repeatedly examined by the moft eminent chemifts. Mr Scheele, as has been related n° 982, *et feq.* has been able to extract an acid from it. His account of it in other refpects is to the following purpofe.

1. All the calculi examined, whether flat and polifhed, or rough and angular, were of the fame nature, and confifted of the fame conftituent parts.

2. The diluted vitriolic acid has no effect upon the calculus, but the concentrated acid diffolves it, and by abftraction from it is converted into the fulphureous kind, leaving a black coal behind.

3. Neither diluted nor concentrated fpirit of falt had any effect upon it.

4. By means of nitrous acid, a new one was produced, and which is poffeffed of fingular qualities, as already mentioned.

5. The folution of calculus in nitrous acid is not precipitated by ponderous earth, nor are metallic folutions fenfibly altered by it.

6. It is not precipitated by alkalies, but grows fomewhat yellower by a fuperabundance of the latter. In a ftrong digefting heat the liquor becomes red, and tinges the fkin of the fame colour. It precipitates green vitriol of a black colour; vitriol of copper, green; filver, grey; corrofive fublimate, zinc, and lead, white.

7. The folution is decompofed by lime-water, and lets fall a white precipitate, foluble in the muriatic acid without any effervefcence: but though there be an excefs of precipitate, the liquor ftill remains acid; which happens alfo with animal earth, and that of fluor diffolved in the fame acids. On evaporation to drynefs, the matter will at laft take fire; but when heated only to a dull red heat in a clofe crucible, it grows black, fmells like burnt alum, and effervefces with acids; being convertible before the blow-pipe into quicklime.

8. Neither this folution, nor the alkaline mixture, is changed by the acid of fugar.

9. The calculus is not changed by acid of tartar, though it is diffolved even in the cold by alkali, when reduced to fuch a ftate of cauflicity as not to difcover the leaft mark of aerial acid. The folution is yellow and taftes fweetifh; and is precipitated by all the acids, even by the aerial. It decompofes metallic folutions, but does not precipitate lime-water; and a fmell of volatile alkali is produced by a little fuperabundance of alkali in the folution. Dry volatile alkali has no effect upon the calculus; but cauftic volatile alkali diffolves it, though a pretty large quantity is required for this purpofe.

10. Calculus is likewife diffolved by digefting in lime-water; and for this purpofe four ounces of lime-water are required to twelve grains of the calculus; but the latter is partly precipitated by adding acids to the folution. By this union the lime-water lofes its cauftic tafte.

11. Calculus is alfo diffolved entirely by pure water; but for this purpofe a large quantity of fluid is required. Eight grains of calculus in fine powder will diffolve by boiling for a fhort time in five ounces of water. The folution reddens tincture of lacmus, but does not precipitate lime-water; and when it grows cold, the greateft part of the calculus feparates in fine cryftals.

12. On diftilling a drachm of calculus in a glafs retort, a volatile liquor was obtained refembling hartshorn, but without any oil; and in the neck of the veffel was a brown fublimate. On heating the retort thoroughly red hot, and then leaving it to cool, a black coal was left, weighing 12 grains, which retained its black colour on a red hot iron in the open air. The fublimate, which had fome marks of fufion, weighed 28 grains, and became white by a new fublimation. Its tafte was fomewhat fourifh, but it had no fmell; it was foluble both in water and in fpirit of wine; but a larger quantity of fpirit than of water was requifite for this purpofe. It did not precipitate lime-water, and feemed in fome refpects to agree with the fal fuccini. 1456

His conclufions concerning its compofition.

From thefe experiments our author concludes, that the human calculus is neither calcareous nor gypfeous; but confifts of an oily, dry, volatile acid, united with fome gelatinous matter. The calculus is an oily falt, in which the acid prevails a little, fince it is foluble in pure water; and this folution reddens the tincture of lacmus. That it contains phlogifton, appears from its folution in cauftic alkalies and lime-water, but efpecially from the effect of the nitrous acid, by which it acquires quite different properties than from folution in alkalies; nor can it be precipitated from this folution. The animal gelatinous fubftance appears on diftillation, by which a liquor is obtained refembling fpirit of hartfhorn, and a fine coal is left behind. 1457

Is found univerfally in urine.

13. Calculus is found diffolved in all urine, even in that of children. On evaporating four kannes of frefh urine to two ounces, a fine powder is depofited as it cools, and a part firmly adheres to the glafs. The precipitated powder readily diffolves in a few drops of cauftic fixed alkali; and has in other refpects all the properties of calculus. Of the fame nature is the lateritious fediment depofited by the urine of thofe who labour under an ague. Mr Scheele fufpected at firft, that there was in this urine fome unknown menftruum which kept fuch a quantity of powder diffolved, and which might afterwards evaporate by expofure to the air; but altered his opinion on perceiving that the fediment was equally depofited in clofe veffels.

14. All urine contains fome animal earth combined with phofphoric acid; by the fuperabundance of which acid,

Calculus.

acid, the earth is kept diſſolved; and by reaſon of this ſuperabundant acid freſh urine communicates a red colour to lacmus. By ſaturation with cauſtic volatile alkali a white powder is precipitated; of which three drachms and an half are obtained from four kannes of urine. It is ſoluble in nitrous acid; and on adding the vitriolic, ſome gypſum is precipitated. On evaporating the nitrous acid, another remained, which precipitated lime-water; and when mixed with lamp-black, afforded phoſphorus by diſtillation; whence it is evident, that the white powder juſt mentioned contained lime and phoſphoric acid.

1458 Why freſh urine reddens lacmus.

1459 Salts, &c. contained in urine.

15. From theſe experiments Mr Scheele concludes, that all urine contains, beſides the ſubſtances already known (*viz.* ſal ammoniac, common ſalt, digeſtive ſalt, Glauber's ſalt, microcoſmic ſalt, ſal perlatum, and an oily extractive matter), a concrete acid, or that of calculus, and animal earth. It is alſo remarkable, that the urine of the ſick is more acid, and contains more animal earth than that of healthy perſons. With regard to the ſal perlatum, it was afterwards diſcovered by Mr Scheele not to be a peculiar acid, but only a phoſphoric acid diſguiſed by a ſmall quantity of foſſil alkali united with it. The analyſis is confirmed by ſyntheſis; for, by combining foſſil alkali with phoſphoric acid, our author obtained a true perlate acid.

1460 Bergman's account of the calculus.

In a ſupplement to Mr Scheele's diſſertation on the calculus, Mr Bergman obſerves, that he could not ſucceed in diſſolving it entirely either in pure water or in the nitrous acid, though the undiſſolved part was the leſs in proportion to the fineneſs of the powder to which the calculus was reduced. The undiſſolved part appears moſt conſpicuous, when ſmall pieces, or ſmall calculi of a few grains weight only, are put into a ſuperabundant quantity of menſtruum, and kept in a degree of heat very near to that which makes water boil. Here it will be obſerved, that the greateſt part of the piece is diſſolved; but that at the ſame time ſome ſmall white ſpongy particles remain, which are not affected either by water, ſpirit of wine, acids, or cauſtic volatile alkali. If the liquor be made fully to boil, theſe particles divide into white rare flocculi, and become almoſt imperceptible, but without any entire diſſolution. Mr Bergman could not collect a ſufficient quantity of them to determine their nature with accuracy; only he obſerved, that when expoſed to a ſtrong heat, they were reduced to a coal which burns ſlowly to aſhes, and is not ſoluble in diluted nitrous acid.

"When calculus veſicae (ſays he) is diſſolved in nitrous acid, no precipitation enſues on adding the acid of ſugar; whence one is readily induced to conclude, that there is no calcareous earth preſent, becauſe this experiment is the ſureſt way to diſcover it. But I have found, in the variety of experiments concerning elective attractions, that the addition of a third ſubſtance, inſtead of diſuniting two already united, often unites both very cloſely. That the ſame thing happens here I had the more reaſon to believe, becauſe the acid of ſugar contains ſome phlogiſtic matter, though of ſuch a ſubtle nature, that, on being burned, it does not produce any ſenſible coal; and the event of my experiment has ſhown, that I was not miſtaken in my conjecture. In order to aſcertain this point, I burned coals of the calculus to aſhes, which were quite white, and ſhowed in every reſpect the ſame phenomena as lime; cauſed ſome effervеſcence during their ſolution in acids, united with vitriolic acid into gypſum, were precipitated by the acid of ſugar, and were partly ſoluble in pure water, &c. Notwithſtanding this, there remains about one-hundredth part of the aſhes inſoluble in aquafortis; being the remainder of the ſubſtance abovementioned, which, together with the concrete acid, conſtitutes the calculus. If the calculus be diſſolved in nitrous acid, the ſolution filtered and evaporated to dryneſs, and the dry maſs calcined to whiteneſs, a calcareous powder is thus likewiſe obtained."

Calculus.

1461 Calcareous earth ſeparated from it by vitriolic acid.

As pure vitriolic acid contains no phlogiſton, our author ſuppoſed, that by dropping it, in its concentrated ſtate, into a ſolution of calculus in nitrous acid, the calcareous earth, if any exiſted in it, would be diſcovered. In this he was not diſappointed; for when the ſolution was ſaturated, ſome ſmall cryſtals were thus immediately ſeparated. Theſe, on examination, were found to be gypſum; and, after being diſſolved in diſtilled water, were precipitated by acid of ſugar. When the ſolution of calculus was very much diluted, no change appeared at firſt on the addition of oil of vitriol; but after a little evaporation, the abovementioned cryſtals began to appear. Some calculi of the bladder or kidneys at leaſt certainly contain lime, but ſeldom more than one half in an hundred parts, or one in 200 parts.

By the aſſiſtance of heat, concentrated vitriolic acid diſſolves the calculus with effervеſcence, and the ſolution is of a dark brown colour. On adding a little water, a kind of coagulation takes place; but by adding more, the liquor again becomes clear, and aſſumes a yellowiſh colour. Mr Bergman agrees with Mr Scheele in ſuppoſing that the muriatic acid has no effect upon the calculus; but he is in no doubt whether it may not extract ſome part of the calcareous earth.

1462 Red colour of the nitrous ſolution accounted for.

The red colour aſſumed by the ſolution of calculus in aquafortis is remarkable. A ſaturated ſolution diſcovers no ſmell of nitrous acid, and if evaporated by itſelf in a large open veſſel, the liquor aſſumes at laſt a deep red colour, and ſcarcely contains any nitrous acid: for, on the one hand, paper tinged with lacmus ſcarce ſhows any redneſs; and, on the other, the colour is deſtroyed irrecoverably by the addition of any acid. By quick evaporation the ſolution at laſt ſwells into innumerable bubbles; the foam grows redder and redder, and at laſt becomes dark red after it is quite dry. This dry maſs communicates its colour to a much larger quantity of water than before, and diſſolves very readily in all acids, even ſuch as have no action on the calculus; but they entirely deſtroy the colour, and that the more quickly in proportion to their degree of ſtrength; even alum has this effect on account of the ſmall quantity of looſe acid it contains. Cauſtic alkalies alſo diſſolve the colouring matter, and deſtroy it, but more ſlowly.

Our author endeavours to account for this red colour produced by the nitrous acid, from the peculiar nature of that acid and the effect it has upon phlogiſton. In order to obtain it, a proportionable quantity of acid muſt be made uſe of, and it ought to be diluted, that there may be no danger of going beyond the neceſſary limit. If too much be uſed, it will not produce the proper effect; but, by reaſon of its ſuperabundance, more or leſs, or even the whole, will be deſtroyed in proportion to the quantity. By pouring it in an undiluted ſtate on powdered calculus, it is con-

converted in a few moments into mere foam. The acid of calculus is the more eaſily ſeparated from the aquafortis by evaporation, as the latter is rendered more volatile by the inflammable particles of the former: alkali added to them both united does not produce any precipitation; a circumſtance generally obſerved where two acids are united. In this caſe both the acids unite with the alkali, according to the different laws of their attraction. The red maſs obtained after deſiccation is, however, very different from the concentrated acid, ſuch as is contained in the calculus; for it is of a darker colour, and very deliqueſcent: the leaſt particle gives a roſe colour to a very conſiderable quantity of water; but the muriatic and other ſtrong acids always certainly deſtroy it; and, in a longer or ſhorter time, produce a colourleſs ſolution. This remarkable change depends, according to our author, more on the action of the nitrous acid upon the inflammable part, than upon any thing remaining behind.—Such red ſpots as are produced upon the ſkin by the ſolution, are likewiſe produced upon bones, glaſs, paper, and other ſubſtances; but more time is required for their becoming viſible, though this too may be a little accelerated by means of heat.

1463 Experiments of Mr Higgins on this ſubject.

The following is an abſtract of Mr Higgins's experiments upon this ſubject.

1. Eight hundred and forty grains of dry and well powdered calculus were introduced into a glaſs retort. It was taken from a laminated ſtone with a ſmall nucleus, which was likewiſe laminated. The outward cruſt appeared very porous, but increaſed in denſity towards the centre. By the application of heat, an elaſtic fluid was firſt ſlowly extricated; and which, on examination, appeared to be compoſed of equal parts of fixed and phlogiſticated air. The laſt portions came over very faſt, and were attended with an urinous ſmell; and, by continuing the diſtillation, it became evident that fixed and alkaline air came over together without forming any union, as they ought, on the common principles of chemiſtry, to have done; though our author is at a loſs to know why they did not unite, unleſs they were prevented by the ſmall quantity of inflammable air which came over along with them.

From the beginning of the 10th meaſure, a black, charry, and greaſy matter began to line the conical tube and air-veſſel adapted to the retort; and as the proceſs went on, the proportion of alkaline air decreaſed, while that of the inflammable air was augmented, until towards the end, when the laſt nine meaſures were all inflammable; after which no more would come over, though the retort was urged with a white heat. On breaking the diſtilling veſſel, a black powder weghing 95 grains was found in it. On digeſting this for an hour in ten ounces of diſtilled water, and then filtering and evaporating it to two ounces, a yellowiſh powder was precipitated, but no cryſtals were formed after ſtanding a whole night. This powder was then ſeparated by filtration, and the liquor evaporated to one ounce; during which time more powder was precipitated. It was then filtered a ſecond time, and the liquor evaporated to half an ounce; when it began to depoſit a white powder, and to emit a ſubacid aſtringent vapour, not unlike that of vitriolic acid. This white precipitate, when waſhed and dried, amounted only to one grain, had a ſhining appearance, and felt very ſoft, not unlike mica in powder. It was not changed, but rather looked whiter by expoſing it to a fierce heat for ten minutes. It diſſolved in diſtilled water without being precipitated by cauſtic volatile alkali. Mineral alkali, acid of ſugar, and nitrated terra ponderoſa, rendered the ſolution turbid; whence our author inferred, that the powder in queſtion was ſelenite.

After the ſeparation of this powder, the remaining ſolution was evaporated to dryneſs with a gentle heat. During the evaporation it continued to emit ſubacid vapours, leaving eleven grains of powder of a dirty yellow colour, having an aluminous taſte. To this powder he added as much diſtilled water as was nearly ſufficient to diſſolve it; after which it was ſet by for three weeks. At the expiration of this term ſeveral ſmall, tranſparent, and cubical cryſtals appeared on the ſide of the veſſel above the ſurface of the ſolution; and theſe likewiſe had an aluminous taſte. The whole was then diſſolved in diſtilled water, and the ſolution filtered. Acid of ſugar produced no change in the liquor for at leaſt five minutes, but an immediate cloudineſs took place on a mixture with volatile alkali; and on filtering the liquor it was again rendered turbid by mineral alkali, though the cauſtic alkali already predominated. Nitrated terra ponderoſa threw down a copious precipitate, and Pruſſian alkali diſcovered a ſmall quantity of iron. This aluminous ſolution left a yellow ſubſtance on the filter; which, when collected and dried, weighed only half a grain: it diſſolved without efferveſcence in nitrous acid; acid of ſugar cauſed no precipitation, but cauſtic volatile alkali threw down a precipitate which diſſolved in diſtilled water. This ſolution was rendered turbid by the acid of ſugar and muriated terra ponderoſa, but no effect was produced by cauſtic volatile alkali or lime-water.

The yellow powder firſt depoſited by the ſolution weighed two grains and a half, and by expoſure to a ſtrong heat acquired a deep orange colour. On digeſtion with diſtilled water, the inſoluble part was reduced to three-fourths of a grain, and appeared to be iron: while the ſoluble part was found to be nothing elſe but gypſum. Our author, however, is of opinion, that this iron is impregnated with a ſmall portion of vitriolic acid, though not in ſuch quantity as to render it ſoluble.

The charred matter remaining in the retort was reduced by lixiviation with water to 80 grains. Theſe were calcined with a red heat in an open fire, but could not be reduced to a grey powder in leſs than three quarters of an hour. When thoroughly calcined and cold, it weighed only 21 grains, which communicated to hot diſtilled water a limy taſte, and gave it the property of turning ſyrup of violets green. Diluted vitriolic acid had no effect upon it, but it was rendered turbid by aerated volatile alkali and acid of ſugar. The remainder when well dried weighed 16 grains, which diſſolved in nitrous acid at firſt with a little effervеſcence; and when this ceaſed, the ſolution went on very ſlowly, until the whole was taken up. Acid of ſugar made no change in the liquid, but the whole was precipitated by cauſtic volatile alkali. Pruſſian alkali threw down a grain, or perhaps more, of blue;

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blue; the precipitate digested with distilled vinegar lost a grain and an half, which was thrown down by caustic volatile alkali. The insoluble part being washed and digested in distilled water for half an hour, was partly dissolved; the solution was not affected by caustic volatile alkali, but acid of sugar and nitrated terra ponderosa caused an immediate cloudiness. Seven grains and an half of the powder, which was insoluble both in acetous acid and distilled water, were readily taken up by diluted vitriolic acid, and precipitated by caustic volatile alkali: the 16 grains last treated, therefore, appeared to contain, of clay 7½ grains; of selenite, six grains; magnesia, one and a half; and of iron, one grain. The proportions of the different ingredients in the whole calculus, therefore, according to Mr Higgins, are as follows:

1464 His account of its component parts.

	Grains.
Iron - -	2½
Selenite - -	11
Clay - -	7½
Alum - -	8
Pure calcareous earth -	5
Aerated magnesia - -	1½
Charry combustible substance -	59
In all	94½

1465 Experiments on the sublimate arising from it on distillation.

In this experiment, a darkish yellow sublimate adhered to the neck of the retort; the inner part next the retort more compact, but the rest of a lamellar spongy texture. This sublimate, when carefully collected, was found to weigh 425 grains, and readily dissolved in eight ounces of hot distilled water. A coaly substance was separated from this solution by filtration, which, when washed and dried, weighed ten grains, and when exposed to a red heat burned with a greenish flame, emitting white fumes, which smelled like vitriolic sal ammoniac: the residuum after calcination weighed half a grain, and was of a whitish colour: appearing insoluble in distilled water, but dissolving with effervescence in nitrous acid. Acid of sugar caused a very small precipitation, which did not take place until the mixture had stood for some time; but caustic volatile alkali instantly threw down a precipitate, which was taken up, when washed, by the acetous acid. The quantity was too small to be examined with greater accuracy; but it seemed to possess the properties of magnesia. The saline solution had the colour of small beer; and, when evaporated to two ounces, did not deposit any sediment, or yield any crystals. The black matter with which the conical tube and air vessel were lined, weighed 28 grains, and adhered so fast to the glass, that it was impossible to collect the whole from the fragments of the glass. When dissolved in distilled water and filtered, four grains of coals, similar to that obtained from the former, were procured; but no signs of crystallization were observed after evaporation to one ounce, and suffering the liquor to stand all night.

By this treatment the solution acquired the consistence of treacle; so that it was plainly not crystallizable, and therefore its analysis was plainly to be attempted after a different method. It was now put into a tubulated glass retort, together with six ounces of distilled water to wash it down. By distillation in a sand-bath three ounces of water were procured, which differed in nothing from common distilled water, but in being coloured with a small quantity of the solution from the neck of the retort. On changing the receiver, about half an ounce of liquor of the same kind came over, after which the distillation began to be attended with an urinous smell. This continued barely perceptible for some time; but when about an ounce and an half had passed over, it became so very pungent, that our author could no longer doubt of its being in a caustic state. A small quantity of mild alkali, however, adhered to the lower part of the neck of the retort, some of which was washed down by the distillation; so that the proportions betwixt the two could not be ascertained. The volatile alkaline solution in the retort had the colour of spirit of hartshorn, and like it became darker coloured by the contact of air; on account of the evaporation of part of the alkali, and the rest becoming less capable of suspending the coaly matter mixed with it.

After all the liquor had passed over, and nothing remained in the retort but a small quantity of black matter, the fire was raised; and, as the heat increased, this black substance acquired a white colour, with a kind of arrangement on the surface, which was occasioned by the heat applied to the bottom of the retort being only sufficient to raise the salt to the top of the matter in the retort; but as the sand became nearly red-hot, white fumes began to appear, which condensed on the upper part of the retort, and a little way down the neck. The process lasted until the matter was nearly red-hot, when the fumes ceased, and nothing more passed over. The sublimate, when collected, was found to weigh 72 grains, a black porous brittle substance remaining on the bottom of the retort, which weighed 12 grains. This residuum, when exposed to a strong heat, emitted white fumes, with a slight alkaline smell; by which process it was reduced, with very little appearance of combustion, to a grey powder weighing three grains, which was accidentally lost.

Five grains of this purified sublimate, mixed with as much quicklime, emitted no smell of volatile alkali; and, when thrown upon a red-hot iron, emitted white fumes. The same effect was produced by a mixture of equal quantities of vegetable alkali and sublimate. The remainder, consisting of 62 grains, was divided into two equal parts; the one of which was mixed with two ounces of distilled water, and on the other was poured 60 grains of vitriolic acid diluted with half an ounce of water. These two mixtures being suffered to remain for six weeks, seemed to be but little acted upon. That with vitriolic acid was then put into a small matrass, and boiled on sand for half an hour with two ounces of distilled water, when the whole was taken up. The solution looked clear, and deposited nothing on standing. Mild mineral alkali had no effect upon it; but mild vegetable alkali threw down a copious sediment in white flocculi, which was redissolved by caustic alkali, lime-water, and partly by mild mineral alkali. Phlogisticated alkali, acid of sugar, and acid of tartar, had no effect upon it. The other portion of sublimate, which had been mixed with distilled water, was very little dissolved; but in pouring it into a matrass some small round lumps were observable on the bottom of the glass. These were

Calculus. six or seven in number, some weighing a whole grain, others not more than one-half. They were very hard and compact, with a smooth surface, and in figure resembling the nucleus of the original calculus. The whole was then put into a matrass with about three ounces of water. On boiling it on sand for three quarters of an hour, about one-half, of it was taken up: the solution passed the filter very clear whilst hot; but on cooling became turbid, and at last deposited white flocculi, which were redissolved on the addition of caustic volatile alkali and lime-water. It turned syrup of violets green; which, however, our author thinks might have been occasioned by its retaining volatile alkali, though it had not the smallest appearance of any such impregnation. He has nevertheless frequently observed, that sometimes the purest vegetable alkali contains volatile alkali, notwithstanding the various operations and degrees of heat it undergoes before it can be brought to the degree of purity at which it is called salt of tartar.

On filtering the solution to separate what had been deposited by cooling, no change was produced in the filtered liquor by mineral alkali; but mild vegetable alkali produced a cloudiness, which was instantly taken up on adding mineral alkali and lime-water. Neither Prussian alkali, nor the acids of arsenic, tartar, sugar, or borax, nor any of the three mineral acids, had any effect upon it.

1466 Experiments with nitrous acid.

2. An hundred and twenty grains of the same calculus were put into a tubulated glass retort, and half an ounce of strong nitrous acid poured upon it. An effervescence immediately ensued; and some part of the extricated aerial fluid being perserved, appeared to be fixed air mixed with a small quantity of nitrous air. When the effervescence ceased, a quarter of an ounce more of nitrous acid was added. On digesting the mixture upon hot sand for an hour, it emitted nitrous vapour and nitrous air; but the latter in very small proportion. When the solution was completed, the whole was poured into a small matrass, and gently boiled till the superabundant nitrous acid was nearly expelled. The solution was of a deep yellow colour and turbid; but on adding five ounces more of water, and digesting it for a quarter of an hour longer, it acquired the colour and consistency of dephlogisticated nitrous acid. On cooling it became somewhat turbid, and in a few days deposited a darkish yellow powder; which, when separated, washed, and dried, weighed little more than a quarter of a grain, and, on examination, was found to be a calx of iron.

1467 Crystallizes on exposure to the sun.

Our author being desirous to know what effect the sun would have upon it, placed it in a window where the sun shone full upon it for four hours every day. Here a little moisture seemed daily to exhale from it, the weather being hot, and the matrass, which had a short wide neck, being only covered, with bibulous paper to keep out the dust. In this situation, in the course of a week, a few very small crystals appeared to float upon the surface. These in time fell to the bottom, where they adhered together so as to form a hard concretion, still retaining a crystalline appearance, but so small and confused, that it was impossible to distinguish their figure; and this deposition of crystals continued for a month, after which it seemed to cease. The solution was then filtered to separate the salt; after which one-half of the liquor was evaporated away, and the rest set in the usual place for a fortnight longer, but no more crystals appeared. The salt, which weighed three grains, was then digested in four ounces of distilled water; but no part seemed to be dissolved. Three ounces of the water were then decanted off, and six drops of vitriolic acid added to the remainder, which by the help of digestion seemed to dissolve the salt slowly; but on adding half an ounce more distilled water, the whole was readily taken up. Acid of sugar had no effect on this solution; but lime-water rendered it turbid. The whole was then precipitated with caustic volatile alkali, and the solution filtered, which likewise threw down the lime from lime-water. The precipitate was then washed, and distilled vinegar poured upon it, which did not take it up; but it was dissolved by marine acid. Phlogisticated alkali had no effect upon it; and the acid of sugar occasioned very little cloudiness after standing three or four hours; from which our author supposed that the matter was phosphorated clay.

The solution, being now free from iron and phosphorated clay, had a subacid taste, and looked clearer, though still retaining a yellow cast. Acid of sugar had no effect upon it; but nitrated terra ponderosa threw down a precipitate, as did likewise the caustic volatile alkali. Mild vegetable alkali caused no precipitation; which our author attributed to the solution of the manganese and clay by the fixed air extricated from the alkali. Two-thirds of the solution were then put into a small glass retort, and two ounces distilled off, which had no taste, but smelled very agreeably, and not unlike rose-water. After all the liquor had passed over, white fumes appeared in the retort, and these were soon followed by an aerial fluid. On collecting some of this, a candle was found to burn in it with an enlarged flame. Nitrous air did not diminish it in the least; and it seemed to be that species of air into which nitrous ammoniac is convertible. No more than 13 or 14 inches of this kind of air could be obtained; and as soon as it ceased to come over, crystals were observed in the lower part of the neck of the retort. On augmenting the heat, a white salt began to sublime and adhere to the upper part of the retort; the operation was continued until the retort was red-hot; but, on breaking it, the quantity of sublimate, was so small, that very little of it could be collected; though, from the small quantity obtained, our author was convinced of its being the same in quality with what was obtained in the former analysis. The salt which crystallized in the neck of the retort was nitrous ammoniac, as appeared from its detonation *per se*, &c. A grey powder was left in the bottom of the retort, which hot distilled water partly dissolved; muriated terra ponderosa, acid of sugar, and vegetable alkali, rendered this solution turbid: but caustic volatile alkali had no effect upon it. The remaining part of the powder which was left by the distilled water, readily dissolved with effervescence in the marine acid, and was precipitated by caustic volatile alkali; the part soluble in distilled water appearing to be gypsum, and that soluble in marine acid to be magnesia.

From all these experiments, Mr Higgins concludes the composition of the human calculus to be vastly different

Calculus.

ferent from what either Mr Scheele or Mr Bergman have supposed it to be. "It appears (says he), that the calculus was composed of the following different compounds blended together; *viz.* selenite, alum, microcosmic salt, mild volatile alkali, lime, and caustic volatile alkali, combined with oil, so as to form a saponaceous mass; calx of iron, magnesia combined with aerial acid, clay enveloped by a saponaceous and oily matter, and the sublimate already described." Considering this to be the true state of the calculus in the bladder, the small proportions of clay, selenite, magnesia, and iron, which are the most insoluble of the ingredients; the great solubility of microcosmic salt and alum, and the miscibility of lime, volatile alkali, and oil, in water; tend to show, that the sublimate is the cementing ingredient. Indeed, its insolubility in water, and property of forming nuclei out of the body, as above observed, leave no room to doubt it. The proportion of the other ingredients, and very likely their presence, depend upon chance, volatile alkali and oil excepted; therefore this sublimate should be the object of our investigation.

1468 Higgins's account of the constituent parts of calculus.

1469 Remarks on the remedies proper for dissolving it.

Mr Higgins concludes his dissertation with some practical remarks concerning the remedies proper for dissolving the stone, for counteracting that disposition in the body which tends to produce it, and concerning the regimen proper for those who are to undergo the operation of cutting for it. "The effect of mild mineral alkali (says he) on the sublimate, is well worth the attention of those who may have an opportunity of trying its efficacy. Mild mineral alkali may be taken in large doses, and continued for a length of time with impunity to the most delicate constitutions, only observing a few circumstances; but this alkali, in a caustic state, must very often be attended with mischievous consequences. Besides, if we consider that it must enter the mass of blood before any part can reach the bladder, and the small portion of the dose taken secreted with the urine, and, lastly, the action of caustic alkali upon animal substances; we shall be at a loss to know on what principle caustic alkalies have been recommended in preference to mild. Soap itself might as well be recommended at once; for soon after caustic alkali is taken, it must be in a saponaceous state. Fixed vegetable alkali should be avoided, and the perference given to the other two alkalies. As it is evident that alkalies have no real action on the stone in the bladder, though their efficacy has been experienced in alleviating the disease when timely administered, their mode of action is only explicable in the following manner: They either prevent the generation of the sublimate in the system, or else keep it in solution in the mass of fluids: and being in the utmost degree of divisibility, its ultimate particles are capable of passing through the most minute emunctories; by which means it is carried off by other secretions as well as the urinary. Thus urine, not being saturated with this matter, acts as a solvent on the stone; and as the most soluble parts are first washed away, it falls through time into fragments of irregular surfaces, which by their friction irritate and inflame the bladder, as has been observed by several practitioners.

"Allowing that the sublimate is the cementing substance in the calculus, and judging, from the effects of alkalies upon it, their *modus operandi* in the constitution, it remains now to inquire into the origin of the calculus. Mr Scheele has found this sublimate in the urine of different persons; and hence inferred, that it was a common secretion; but it still remains to be ascertained, whether there be a greater quantity of it procured from the urine of patients who labour under this disorder than in those who do not? If this should not be the case, may not a deficiency of volatile alkali in the constitution be the cause of the concretions in the kidneys, bladder, &c.; or, which must have the same effect, too great a proportion of acid, which, uniting with the alkali, may take up that portion which would have kept the sublimate in solution until conveyed out of the system by the urinary and other secretions; and may not this be the phosphoric acid? If this latter should be the case, an increase of microcosmic salt must be found in the urine; but if the former, a decrease of the volatile alkali, and no increase of the neutral salt. The small quantity of phosphoric acid found in the calculus proceeds from the solubility of microcosmic salt. Do not volatile alkali and phosphoric acid constitute a great part of the human frame? and is their not a process continually carried on to generate these in the system? and is not this process liable to be retarded or checked by intemperance, &c. which may vary their quantities and proportions? and may not a due proportion of these be necessary to a vigorous and sound constitution? If so, no wonder that an increase or deficiency in either or both of these should be productive of several disorders."

On this subject, however, our author has not had sufficient leisure to make the experiments necessary for its elucidation. Indeed, it seems not easy to do so; as, in his opinion, at least 500 would be required for the purpose. "That the urinary sublimate is present in tubercles found in the lungs of persons who die of pulmonary consumptions, and likewise in what are vulgarly called *chalk stones*, is what I have experienced: but in what proportion, or whether in quantities sufficient to cause the concretion, is what I cannot say; for I have had but a few grains of each to examine. I have every reason to suspect, that consumptions and scorbutic complaints very frequently arise from a superabundance of this sublimate in the system; and that it is chiefly the cause of the gout and rheumatism, and solely the cause of the stone in the bladder. I make no doubt but these disorders generally proceed from obstructions: and it is probable, that either a precipitation of this sublimate in the system, or else a deficiency of some other secretion, which would hold it in solution until conveyed out of the body, may be the chief cause of those obstructions; and likewise, that different degrees of precipitation may produce different symptoms and disorders.

1470 Sublimate of calculus found in consumptive and gouty people.

"That mineral or volatile alkali and bark have been useful in the above disorders, has been affirmed by experienced physicians; and I know an instance myself of mineral alkali and nitrous ammoniac being serviceable in a pulmonary complaint of some standing.

"With respect to the stone, when it acquires a certain magnitude, it is absurd to attempt to dissolve it in the bladder, it wastes so very slowly; and during this time the patient must suffer vast pain, particularly when

Vitriolic æther.

when the stone acquires a rugged surface: therefore cutting for it at once is much preferable.

"Mineral alkali taken in the beginning of the complaint, and before the stone accumulates, will no doubt check its progress, and may in time change that disposition in the habit. Patients who are cut for the stone should, I think, take mineral alkali for some time when the wound is healed, but not before, for fear of bringing on a mortification."

Nitrous acid.

A P P E N D I X;

Containing such Discoveries as have appeared since the Compilation of the Article, and which could not be inserted in their proper Places.

I. *Vitriolic Ether.*

1471 Various methods of rectifying vitriolic ether.

M. Pelletier formerly proposed a method of rectifying this fluid by putting manganese into the vessels; but as the vitriolated manganese might perhaps communicate some injurious quality, another method is proposed by M. Tingry. After first drawing off the ether, he adds a diluted solution of volatile alkali, and avoids as much as possible the dissipation of the vapours: the ether is then redistilled. It may afterwards in this way be washed more safely, and with less loss. The little proportion of the ether which is separated in the water, may be again recovered, or the water may be again employed for the same purpose. M. Lunel proposes calcined magnesia for this purpose, as its salt is not soluble; though perhaps pure terra ponderosa might be better.

II. *Nitrous Acid.*

1472 Mr Higgins's observations.

On this subject Mr Higgins has several curious and interesting observations. "It is not an easy matter (says he), to ascertain exactly the greatest quantity of dephlogisticated air, which a given quantity of nitrous acid may contain. I always found nitre to vary, not only in its product of phlogisticated and dephlogisticated air, but likewise in their proportion to one another. The purest nitre will yield, about the middle of the process, dephlogisticated air so pure as to contain only about $\frac{1}{15}$ of phlogisticated air. In the beginning, and nearly about the latter end of the process, air will be produced about twice better than common air. On mixing the different products of a quantity of pure nitre, it was found that, by exposure to liver of sulphur, $\frac{1}{7}$ part was left unabsorbed; and this was the utmost purity in which I obtained dephlogisticated air from nitre.

1473 Account of its constituent parts by M. Lavoisier.

"According to M. Lavoisier, 100 grains of nitrous acid contain $79\frac{1}{2}$ of dephlogisticated air, and $20\frac{1}{2}$ of phlogisticated air, which is not quite four to one. But his experiments contradict this; for whatever mode he adopted to decompose nitrous acid, it appeared that the proportion of dephlogisticated air was nearly as five to one of phlogisticated air.

1474 By Mr Cavendish.

"Mr Cavendish has proved, that nitrous acid may be formed by taking the electric spark in a mixture of three parts of phlogisticated air, and seven of dephlogisticated air, which is but $\frac{1}{7}$ more of dephlogisticated air than nitrous air contains; which may apparently contradict M. Lavoisier's, as well as my own, estimation of the proportion of the constituent principles of nitrous acid, when in its perfect state. The red nitrous vapour contains three parts of nitrous air and one of dephlogisticated air, or one of phlogisticated and three of dephlogisticated air; but nitrous vapour may be formed with a less proportion of dephlogisticated air; and which, though it may not be so condensible as a more perfect nitrous vapour, yet will, when in contact with pure alkali, unite with it, and form nitre, as was the case in the experiment of Mr Cavendish. The common straw-coloured nitrous acid contains more dephlogisticated air than the red nitrous acid or vapour; the proportion appears to be about four to one; but the colourless contains about five of dephlogisticated to one of phlogisticated air.

1475 Method of obtaining colourless nitrous acid.

"Having once a charge of nitrous and vitriolic acid in a green glass retort, I put it in a sand-pot to distil; but the pot being small, the edge came too near the retort, about a quarter of an inch or more above the charge; which, before the process commenced, and when it acquired more than the heat of boiling water, cracked it all round in that direction. Being thus situated, I was obliged to withdraw the fire, and, before the charge got cold, to ladle it into an earthen pan. On introducing it into a fresh retort, I obtained from it nitrous acid nearly as colourless as water. The vitriolic acid used in this process not being very perfect, the goodness of the nitrous acid was attributed to the purity of the nitre from whence it was distilled; but in another process, though the same nitre was used with much purer vitriolic acid, the produce was of an high straw colour. On recollecting the abovementioned circumstance, the vitriolic acid and nitre were next mingled in due proportion, and exposed in an earthen pan set in sand, to nearly the heat of boiling water, for half an hour or more, continually exposing fresh surfaces to the air. When the charge was quite cold, I introduced it into a retort, and distilled as colourless nitrous acid as the former. As no nitrous air was emitted during digestion, it must have imbibed dephlogisticated air from the atmosphere."

1476 How to set charcoal on fire by means of nitrous acid.

Mr Proust found, that strong nitrous acid will set fire to charcoal if it be rendered very dry. He likewise remarked, that charcoal exposed to the air a few hours after calcination, was unfit for the experiment. Charcoal, he observes, attracts moisture very forcibly. The first effect of the charcoal on the nitrous acid, he observes, is to withdraw a portion of its water from it; by which it is rendered highly concentrated, at the same time that the condensation of the water heats the charcoal in a small degree, but sufficiently to volatilize a nitrous vapour; which, as soon as it reaches that portion of dry charcoal next the humid part, is condensed

Nitre. denſed by it, and generates heat enough to promote the decompoſition of the nitrous acid. Hence we ſee why the experiment will not ſucceed if the acid be poured on the ſurface of the charcoal.

1477 Effect of nitrous acid on blood. The effect of nitrous acid on blood, according to Mr Higgins, is very ſingular. Two parts of blood procured freſh at the butchers, one of ſtrong nitrous acid, and about one fifth of the whole of water, were digeſted in the heat nearly of boiling water (freſh portions of water being occaſionally added until the whole of the acid was expelled), when it acquired almoſt the colour, and exactly the taſte, of bile. When mixed with a large quantity of water, it acquired a fine yellow colour; and, on ſtanding, depoſited a ſubſtance of a brighter yellow, though the ſupernatant liquor ſtill retained a yellow colour and bitter taſte, but not ſo intenſely as when the precipitate was ſuſpended in it. The different ſtages of this proceſs were well worthy of obſervation. No nitrous air was produced, and the acid was expelled in the ſtate of a white vapour. The liquor was found to increaſe in bitterneſs as the acidity vaniſhed. About the middle of the proceſs, the ſolution firſt taſted acid, but was quickly ſucceeded by a bitter ſenſation. It appears that the nitrous acid took dephlogiſticated air from the blood; for though red nitrous acid was uſed, it was expelled in a perfect ſtate.

III. *Nitre.*

Though the artificial generation of the nitrous acid, from a mixture of dephlogiſticated and phlogiſticated air, is now ſufficiently underſtood, yet we do not well know in what manner nature performs the operation. Some chemiſts, particularly M. Thouvenal, have found, that putrefaction favours the production of nitrous acid. All animal ſubſtances, during their decay, give out a vaſt quantity of phlogiſticated air; therefore, if dephlogiſticated air be preſent, it will unite to the phlogiſticated air in its naſcent ſtate, and

1478 Nitre generated without putrefaction. form nitrous acid: but Mr Higgins has obſerved, that nitrous acid may be generated in plenty where there is no putrid proceſs going on. "The chemical elaboratory at Oxford (ſays he) is near ſix feet lower than the ſurface of the earth. The walls are conſtructed with common limeſtone, and arched over with the ſame; the floor is alſo paved with ſtone. It is a large room, and very lofty. There are ſeparate rooms for the chemical preparations, ſo that nothing is kept in the elaboratory but the neceſſary implements for conducting experiments. There is an area adjoining it on a level with the floor, which, though not very large, is ſufficient to admit a free circulation of air. The aſhes and ſweepings of the elaboratory are depoſited in it. There is a good ſink in the centre of this area, ſo that no ſtagnated water can lodge there. Notwithſtanding all this, the walls of the room afford freſh crops of nitre every three or four months. Dr Wall, who paid particular attention to this circumſtance, and who told me it contained fixed vegetable alkali, requeſted I would analyſe it, and let him know what it contained. I found that two ounces of it contained ſix drachms of nitrated fixed vegetable alkali, and three of calcareous nitre. The nitre firſt appears in ſmall whitiſh filaments as fine as cob-web, which, when they get a little larger, drop off; ſo that they never acquire ſufficient growth to diſtinguiſh their figure to a naked eye. On finding that they contained fixed vegetable alkali, I concluded that it proceeded from minute vegetation; but in this I was miſtaken; for I found that they were ſoluble in water, and that they detonated with charcoal at every ſtage of their growth. Having ſwept this ſaline effloreſcence from the wall, I dug deep into it, but could not obtain nitre from it. When a part had been white-waſhed, it yielded nitre, but not ſo abundantly as a neighbouring ſpot which had not been treated in the ſame manner. Hence it is evident, that nitrous acid may be formed without the aſſiſtance of putreſcent proceſſes in a ſtill damp air, where there is a ſubſtance to attract it when half formed, whereby it is in time brought to perfection. The above facts moreover prove, that fixed vegetable alkali is a compound."

Marine acid.

IV. *Marine Acid.*

Mr Higgins informs us, that he has, with a view to decompoſe ſea-ſalt, mixed it with mangane ſe in various proportions, and expoſed them in a reverberating furnace in a well cloſed crucible for three hours, to a heat nearly ſufficient to melt caſt iron. In the ſame manner he treated mangane ſe, ſalt, and charcoal, as well as clay, ſalt, and charcoal, and ſalt and clay alone, with very little ſucceſs. He treated calcined bones, ſalt, and charcoal, and calcined bones and ſalt, as well as lime and ſalt, in the ſame manner, without effecting any apparent change in the ſalt. He was informed, however, by Mr Robertſon, apothecary in Biſhopsgate-ſtreet, that he had partially alkalized it, by expoſing it with clay to a fierce heat; but that ſoon after it got into contact with air, it became neutral again. "If common ſalt and litharge be fuſed (ſays Mr Higgins), it is in part decompoſed; the acid ſuffers no decompoſition, but unites with the lead; whereby it acquires, when the ſaline matter is waſhed away, a yellow colour. It is evident (adds he) from theſe facts, that the baſis of marine acid is a combuſtible body, and quite different from light inflammable air, charcoal, or any known inflammable ſubſtance; and that it attracts dephlogiſticated air with greater force than any ſubſtance hitherto diſcovered. Though charcoal will decompoſe all other acids, except a few, when united to bodies which will fix them until they acquire a ſufficient degree of heat, yet it has no effect upon marine acid." 1479 Unſucceſsful attempts to decompoſe ſea-ſalt

According to Fourcroy, if alkaline air be confined by mercury, and dephlogiſticated marine acid air be added to it (which muſt be done quickly, as the acid air would diſſolve the mercury), each bubble produces a ſlight detonation, and furniſhes a very amuſing ſpectacle.

Though in Britain the diſtillation of the ſpirit of ſalt with clay has long been entirely laid aſide for the proceſs with oil of vitriol, yet it is ſtill practiſed in other countries, and may be effected in the following manner: Having previouſly decrepitated the ſalt, and dried the clay, they are then to be ground, mixed, and ſifted together. The mixture is next to be worked with a ſpatula, and then with the hands, until it is brought into a moderately ſtiff and uniform maſs. 1480 Method of diſtilling ſpirit of ſalt with clay.

Marine acid.

This is to be divided into balls about the size of a pigeon's egg, so that they can pass through the neck of the retort; but before they are put into the distilling vessel, it is proper to dry them thoroughly. The retorts must be of stone-ware, and carefully coated, in order to prevent them from breaking with the intense heat to which they are exposed. They are to be filled two-thirds full of materials, and the distillation must be performed in a reverberatory furnace. The receiver at first is not luted on, because that which rises in the beginning of the distillation, being very aqueous, is to be put by itself. When this has come over, another receiver is then to be applied, and cemented with fat lute, and covered with a cloth daubed with a mixture of lime and the whites of eggs. The heat is to be raised until the retort is red-hot, and continued in this degree until the distillation ceases.

Various proportions of clay and salt have been recommended for this process; but it seems probable that not less than ten parts of clay to one of salt, as Pott has directed, will be found necessary. Instead of the clay, some direct the use of bole; but this is inconvenient on account of the iron it contains. Powdered talc has also been recommended, but this is not always free from iron; and where a very pure spirit is wanted, there is a necessity for having recourse to oil of vitriol, and glass or stone-ware vessels. As the marine acid cannot be separated from the earthy mixtures abovementioned, but by means of moisture, M. Beaumé advises to moisten the residuum, and repeat the distillation, by which more acid will be obtained.

1481 Effect of marine acid upon phlogistic matters.

As the marine acid has very little action upon phlogistic matters, it cannot therefore affect oils, either expressed or essential, in a manner similar to the vitriolic or nitrous. M. Marges, however, has observed yellow crystals resembling amber formed in bottles, containing a mixture of oils and marine acid of moderate strength, which had stood for several months. The little effect which the marine acid has upon these substances was first supposed to be owing to its want of phlogiston in itself; but when it was afterwards found, that, by the application of certain substances which have a great attraction for phlogiston, the marine acid was rendered capable of uniting very readily with inflammable matters, the former theory was abandoned. It was now asserted, that the acid, instead of containing no phlogiston, was naturally endowed with a very considerable quantity; and that, in its new state, it was dephlogisticated by the substances applied. On the other hand, the antiphlogistians asserted, that no change was thus made upon it, farther than adding a quantity of pure air, which they suppose to be the basis of all acids. On this subject, however, M. Cornette maintains, that the marine acid seems to have so little action upon inflammable substances, merely because it is weaker than the rest; and likewise that it is often previously combined with some inflammable matter, by which its attraction is prevented. He maintains, that if the marine acid be concentrated in such a manner as to render its specific gravity to that of water as 19 to 16, it will then act upon oils with heat and effervescence, reducing them to a black and thick substance, and even burning them to a kind of coal. Some experiments have been made by Mr Hasse, with a view to investigate the action of the marine and vitriolic acids upon balsams and oils; for which purpose he mixed two drachms of smoking spirit of salt with one of each of the oily substances to be tried. The results were, that Canada balsam gained one scruple in weight; balsam of capivi 19 grains; storax, and Venice turpentine, each one scruple; asphaltum 18 grains; but the essential oils of anise-seed, benzoin, bergamot, coriander, and many others, were not altered in any degree. The action of this acid upon inflammable matters, however, is augmented by its being reduced into the form of air.

Gmelin relates, that, by distilling a mixture of five parts of salt, twelve of spirit of wine, and four of vitriolic acid, to which he had previously added one or two parts of water, he obtained a completely dulcified spirit of salt, and an imperfectly dulcified spirit of vitriol, upon rectifying the liquor.

1482 Glass corroded by it.

Homberg found, that glass was corroded by the marine acid: and his observation has been confirmed by Dr Priestley; who finds that its corrosive power is augmented by confining the acid in tubes hermetically sealed. Its power is exerted not only on flint-glass, but even on common green glass; though more powerfully on the former, where it chiefly attacks the red-lead used in its composition. By inclosing marine acid gas for some weeks in a glass tube exposed to heat, an incrustation was formed on the inside, while the air was diminished to $\frac{1}{4}$ of its original bulk, one half of which was absorbed by water; the other was phlogisticated air.

1483 Cause of the yellow colour of marine acid.

The marine acid is generally met with of a yellow or reddish colour, which by Macquer is given as one of its characteristic marks. In general, however, this colour is thought to proceed from iron; but Dr Priestley has found that it may be produced by many different substances; and his observations have been confirmed by Scheele and other chemists. The Doctor is of opinion that it is occasioned for the most part, if not always, by a mixture of earth; and he was able to communicate it by means of calcined oyster-shells, calcined magnesia, pipe-clay, or pounded glass; but not by wood-ashes, from whence the air had been expelled by heat. It was effectually discharged by flowers of zinc, a coal of cream of tartar, and by liver of sulphur; but he found that the colour which had been discharged by liver of sulphur, would return by mere exposure of the acid to the atmosphere, but not that which had been discharged by flowers of zinc.

Dephlogisticated spirit of salt.

1484 Expeditious method of bleaching linen.

When the action of this vapour upon any thing is to be examined, the substance must be put into a bottle in such a manner as to remain in contact with it; or it may be put into a glass tube, which is suspended and fixed to the stopper, and thus introduced into the bottle.—From its property of destroying all vegetable colours, it promises to be of very considerable use in the arts, provided it could be had in sufficient quantity, and cheap. It bleaches yellow wax, and when properly applied to linen, will whiten it sufficiently, and without injury in a few hours. This may be effected by steeping the linen for that space of time in water impregnated with the dephlogisticated marine gas. It unites with this fluid rather more easily than fixed air.

Ber-

Marine acid. Berthollet, in order to impregnate water with it without exposing the operator to the fume, which is extremely disagreeable, put the mixture of marine acid and manganese into a retort. To this he applied first an empty bottle, and then several others filled with water, and communicating with each other by means of bent tubes; surrounding the whole with ice. When the water in the bottles was saturated, the gas became concrete, and fell to the bottom; but with the smallest heat it arose to the top in bubbles. The specific gravity of the saturated water was to that of distilled water, when the thermometer was only five degrees above the freezing point, as 1003 to 1000. This impregnated water is not acid, but has an austere taste, and has the same action as the gas, though in a weaker degree. Mr Berthollet has observed, that the addition of alkalies does not prevent, but rather promotes, the discharge of colours; for which reason he directs to add a fixed alkali to the impregnated water in which linen is to be steeped for bleaching. This is the expeditious method hinted at under the article BLEACHING; but which has not hitherto come into use, principally through the high price of the dephlogisticated gas.

The dephlogisticated marine acid does not discharge all colours with equal ease. Those of litmus and syrup of violets are entirely destroyed, and turned white. The colouring matter of Brazil-wood, and some green parts of plants, retain a yellow tint. The leaves of evergreen plants resist its action for a long time, and at last only acquire the yellow colour which they assume by long exposure to the air; and in general the changes of colour which vegetable matters suffer from this gas, are similar to those which take place on long exposure to the air; and by this operation the gas is converted into common marine acid.

1485 Effect of the dephlogisticated acid on phlogistic matter, &c.

Oils and animal fats are thickened by this gas; and by these and other inflammable substances it is reduced to the state of common marine acid. Light is said to produce the same effect. It unites with fixed alkalies and calcareous earths, but without any sensible effervescence; and thus they lose their peculiar taste and colour. M. Berthollet having boiled in a retort, to which a pneumatic apparatus was affixed, some of the dephlogisticated marine acid liquor with mineral alkali, thus obtained a considerable quantity of elastic fluid, composed partly of fixed air, partly of the air contained in the vessels, and partly of air considerably purer than that of the atmosphere. The result of the combination was common salt. On repeating the experiment with lime, no fixed air was obtained; but that which came over became gradually more and more dephlogisticated. Volatile alkali, even when caustic, occasioned an effervescence, and emitted a peculiar kind of air, which was neither fixed nor dephlogisticated, but of a peculiar kind.

Green vitriol is changed to a red by the dephlogisticated gas, but the colour of blue and white vitriol is not affected. By the assistance of light, it acts upon phosphorus, and the result is phosphoric and common marine acids. It does not dissolve ice nor camphor; in which respects it differs from the common marine acid gas.

1486 Marine ether.

On mixing marine acid, manganese, and spirit of wine, and distilling them with a very gentle heat, little air of any kind is produced, but a quantity of ethereal liquor very slightly acid. The proportion used by Pelletier were an ounce and a half of manganese, five ounces of concentrated marine acid, and three ounces of spirit of wine. "In this process (says Mr Kier), the whole of the dephlogisticated acid seems to have united with the spirit of wine, and to have formed ether. The difficulty of combining marine acid with spirit of wine, so as to form an ether, is well known, and though there have been some approximations to it, yet the only instances in which it has been completely effected, have succeeded in consequence of the marine acid being dephlogisticated; by which its action on spirit of wine, as well as on all inflammable matters, is greatly increased."

M. Pelletier has observed, that when we put a bit of phosphorus into dephlogisticated marine gas, the former is immediately dissolved, and a light is perceived, the vessel being filled at the same time with white vapours. He has likewise observed, that sea-salt, with an excess of pure air, thrown into heated vitriolic acid produces a small detonation. To make this salt in quantity, take, for instance, ten pounds of sea-salt, mixing it with from three to four pounds of manganese, pour on the mixture ten pounds of vitriolic acid, and distil with Woulfe's apparatus. Pass the disengaged acid through a solution of fixed vegetable alkali, either caustic or otherwise. A little more than ten ounces of the new marine salt with excess of pure air is obtained, and a quantity of salt of Sylvius, or digestive salt. The salt with excess of pure air crystallizes first, and by means of repeated crystallizations, is entirely disengaged from the other.

1487 Method of procuring a detonating salt from the acid in quantity.

V. *AQUA REGIA.*

1488 Various ways of preparing aqua-regia.

THIS acid, which is named from its property of dissolving gold, is compounded of the nitrous and marine acids. Gold and platina cannot be dissolved in any other menstruum, nor can regulus of antimony and tin be so easily dissolved by any other as aqua-regia. It may be made various ways. 1. By adding the two acids to each other directly. 2. By dissolving in the nitrous acid some salt containing marine acid, particularly sal ammoniac and common salt. 3. By distilling nitrous acid from either of these salts. And, 4. In Dr Priestley's method of impregnating marine acid with nitrous acid vapour.

1489 Differences between these acid liquors.

The only difference between those liquors prepared by the methods abovementioned is, that when sal ammoniac or sea-salt are dissolved in the nitrous acid, the aqua-regia contains a quantity of cubic nitre, or nitrous ammoniac, which, tho' it cannot much affect the acid as a solvent, may make a considerable difference in the nature of the precipitate. Thus, gold precipitated from an aqua-regia formed by the pure nitrous and marine acids, does not fulminate, though it does so when precipitated from one made with sal ammoniac. There are no established rules with regard to the proportions of nitrous and marine acids, or of nitrous acid and sal ammoniac, which ought to be employed for the preparation of aqua-regia. The common aqua-regia is made by dissolving four ounces of sal ammoniac in 16 ounces of nitrous acid; but these proportions must be varied, according to the nature of the intended solution.

Borax. tion. Platina, for instance, is dissolved in the greatest quantity by equal parts of the two acids; regulus of antimony by four parts of nitrous acid to one of marine; and, in general, the greater the quantity of marine acid employed in the mixture, the less are the imperfect metals, particularly tin, calcined or precipitated by it. A mixture of two parts of spirit of nitre, and one of spirit of salt, dissolves nearly an equal weight of tin into a clear liquor, without forming any precipitate; but, for this purpose, the operation must be conducted slowly, and heat avoided as much as possible.

VI. *Borax.*

In a memoir in Crell's Chemical Annals, by M. Tychson, the author shews, by different experiments,
1490 that it may sometimes be purified by solution, filtra-
Methods of tion, and evaporation only; but that sometimes the
purifying operation is more easy and effectual by previous calci-
borax. nation; but then the product is a little lessened, especially if the calcined mass be not well powdered, and then boiled sufficiently in water. Powder of charcoal, he says, may be sometimes advantageously employed in the purification; but in general there is no difference between the crude and purified borax, except in the addition of extraneous matters; at least, as the quantity of acids is the same, the addition of mineral alkali is useless: these extraneous matters are an animal fat, and a sand composed of clay, lime, and a martial earth. If the oily matter of tartar be separated by passing the lixivium through a stratum of clay, as is supposed in the preparation of the crystals at Montpelier, it would suggest a method of greatly abridging the process of the purification of borax.

VII. *Acid of Borax, or Sedative Salt.*

1491
Methods of preparing the sedative salt from borax. On the preparation of this salt Mr Beaumé observes, that a little more acid ought to be added to the borax than what is just sufficient to saturate its alkaline basis. Unless this be done, the sedative salt remains confounded with the other saline matters in the solution, and of consequence the crystallization must be disturbed. The salt, though formed in an acidulated liquor, is easily deprived of its superfluous acid by draining upon paper. It does not crystallize as soon as the stronger acid separates it from its basis, even tho' the solution of borax had been previously made as strong as possible; but this delay is occasioned by the heat of the liquor; for as soon as it cools, a considerable quantity of crystals is formed.

The acid of borax does not fall into powder when
1492 exposed to the air, but rather attracts a little moisture
Its proper- from it. Its taste is at first somewhat sourish, then
ties. cooling and bitterish; and lastly, it leaves an agreeable sweetness on the tongue. It makes a creaking sound, and feels a little rough between the teeth; and when vitriolic acid is poured upon it, exhales a transient odour of musk. It is soluble, according to some chemists, in the proportion of one to 20 in cold water, or of one to eight in boiling water. Wenzel informs us, that 960 grains of boiling water dissolve 434 of the salt; while, on the other hand, Morveau asserts, that he could dissolve no more than 183 grains in a pound of distilled water. Rouss informs us, that fixed air prevents the solution of the salt in water; and Morveau, that its solubility is much augmented by cream of tartar. When previously made red hot, it dissolves in water with a smell of saffron, and a grey powder of an earthy appearance is precipitated, which is soluble in vitriolic and marine acids, and may be again precipitated in the form of sedative salt.

Acid of borax and its combinations.

Phlogisticated alkali makes no change on sedative salt in solution; but paper dipped in a solution of it in vinegar, and afterwards dried, burns with a green flame. It is capable of vitrification, though mixed with fine powder of charcoal; and with soot unites into a black mass like bitumen; which, however, is easily soluble in water, and can scarce be reduced to ashes, but partly sublimes. By the assistance of heat it dissolves in oils, especially those of the mineral kind; and with these it yields solid and fluid compounds, which gives a green colour to spirit of wine. Rubbed with phosphorus it does not prevent its inflammation; but a yellow earthy matter is left behind. It seems also to give to white and red arsenic a great degree of fixity, so as even to become vitrescible in the fire; and this property it communicates also to cinnabar. When mixed and heated with powder of charcoal, it forms no liver of sulphur.

Sedative Salt combined,

1. *With volatile alkali.* The produce of this is a peculiar ammoniacal salt, which does not evaporate when thrown on burning coals, or otherwise intensely heated, but melts into glass of a greyish colour, but transparent, which cracks when exposed to the air; and, on dissolution in water, shoots into small crystals, which appear to have lost none of their alkaline basis. It may be decomposed by the acetous as well as the mineral acids, and by fixed alkalies and lime.

2. *With magnesia* this acid shoots into irregular crystalline grains soluble in vinegar and acid of ants; in which liquids they crystallize like small needles joined together at right angles. They are decomposed by all other acids, and likewise by spirit of wine. In the fire, however, they melt easily without any decomposition; and in the dry way sedative salt decomposes all the earthy salts formed by magnesia and any of the volatile acids.

3. *With pure earth of alum*, sedative salt forms a salt very difficult of solution, when one part of earth is ground with four times its weight of sedative salt and water. The same kind of earth, mixed with half its weight of sedative salt, forms a hard grey mass, resembling pumice stone; part of which is soluble in water, and yields a mealy sediment, together with some sedative salt unchanged.

4. *With siliceous earth* the sedative salt does not unite in the moist way; but, on melting one part of acid with two of this earth, we obtain a frothy, hard, greyish-white mass, from which, however, the acid may be again procured.

5. *Gold* is not acted upon in the wet way by acid of borax; nevertheless Rouss observed, that when sedative salt was melted with gold-leaf, it did not vitrify, but became frothy and hard, did not colour the flame of spirit of wine, and only a little of it was soluble in water in which sedative salt had been crystallized.

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Acid of borax and its combinations.

A ſolution of borax in which ſedative ſalt was diſſolved, did not precipitate gold.

6. *Platina* is not precipitated from aqua-regia by ſedative ſalt.

7. *Silver* is not affected by melting with an equal quantity of ſedative ſalt; but the latter is vitrified in ſuch a manner as to become inſoluble in water.

8. *Mercury* is not diſſolved either in the dry or wet way; but a ſolution of borax ſaturated with ſedative ſalt precipitates it in a yellow powder from nitrous acid.

9. *With copper.* On this metal ſedative ſalt acts but weakly, even when the ſolution is boiling hot; nevertheleſs, as much of the metal is diſſolved, as gives a little white precipitate on the addition of fixed alkali; but volatile alkali does not throw down a blue precipitate, nor turn the ſolution of that colour. The ſolution of borax precipitates all ſolutions of copper in acids, and then the ſedative ſalt unites with the copper in form of a light green jelly, which, after drying, is of very difficult ſolution in water. Bergman ſays, it is of an agreeable green colour, which it preſerves after being dried; and that, when expoſed to the fire, it melts into a dark-red vitreous ſubſtance. Wenzel aſſerts, that by long continued trituration of copper filings with ſedative ſalt he obtained a ſolution of the metal, which yielded cryſtals on being evaporated. With twice its weight of copper in a covered crucible, an inſoluble vitreous maſs was obtained.

10. *Tin* is not apparently acted upon by boiling with ſedative ſalt; nevertheleſs, the ſolution becomes turbid on the addition of an alkali. By melting the calx with half its weight of ſedative ſalt, we obtain a black maſs like the dark coloured tin ore. By rubbing for a long time filings of tin with ſedative ſalt and water, and afterwards digeſting the mixture with heat for one day, an hard, ſandy, and irregularly ſhaped ſalt was obtained, which, by diſſolution in water, yielded tranſparent, white, polygonous cryſtals; and a ſalt of of the ſame kind was obtained from the ſlag produced by melting equal parts of ſedative ſalt and tin filings.

11. *Lead* is not acted upon directly; but, on adding a ſolution of borax to ſolutions of the metal in vitriolic, nitrous, marine, or acetous acids, the ſedative ſalt unites with the lead. One part of ſedative ſalt with two of minium gives a fine, greeniſh-yellow, tranſparent, and inſoluble glaſs.

12. *With iron.* The acid of borax diſſolves this metal more eaſily than any other. The ſolution is amber-coloured, and yields an ochry ſediment, with cluſters of yellow cryſtals containing a little iron. The metal is precipitated by borax from its ſolutions in vitriolic nitrous, marine, and acetous acids, and the precipitates are ſoluble in ſedative ſalt. A ſolution of iron may alſo be obtained by melting this ſalt with iron filings, and lixiviating the maſs.

13. *Zinc* communicates a milky colour by digeſtion with ſolution of ſedative ſalt. By evaporation it affords a confuſed ſaline maſs, and a white earthy powder by precipitation with alkali. Flowers of zinc, melted with ſedative ſalt, form a light green inſoluble ſlag.

14. *Biſmuth*, in its metallic ſtate, is not acted upon by ſedative ſalt, but is precipitated by borax from a mixture of vitriolic and marine acids, in form of a very white powder, which keeps its colour when expoſed to air, and melts in the fire to a white, tranſparent, and permanent glaſs.

Acid of borax and its combinations.

15. *Regulus of antimony* is not acted upon directly, but its calx is diſſolved when precipitated by borax from a ſolution in aqua-regia.

16. *White arſenic* unites with ſedative ſalt either in the dry or moiſt way, and forms a cryſtallizable compound, forming either pointed ramifications, or white, greyiſh, and yellowiſh ſaline powder.

17. *On regulus of cobalt* the acid has no direct action; but borax precipitates it from its ſolution, and the calx melts with the ſalt into a ſlag of a bluiſh-grey colour; and this, by lixiviation and evaporation, affords a ſedative ſalt impregnated with cobalt, of a reddiſh white colour, and of a ramified form.

18. *Nickel* is precipitated from its ſolution, and the ſedative ſalt unites with it into a ſaline ſubſtance difficult of ſolution.

A variety of opinions have been formed concerning the nature of ſedative ſalt. M. Beaumé and M. Cadet particularly have made a great number of experiments on the ſubject; but as none of theſe have led to any certain concluſion, we forbear to mention them at preſent. Thoſe of Meſſrs Exſchaquet and Struve have 1493
indeed eſtabliſhed ſome kind of relation between the acids of borax and phoſphorus, and they have made ſeveral attempts to analize the former, but with little ſucceſs. The moſt remarkable of theſe experiments are the following. 1. They diſtilled, with a ſtrong heat, two parts of phoſphoric acid evaporated to the conſiſtence of honey, one of ſedative ſalt, and two of water. Towards the end of the diſtillation a very acid liquor was obtained; and the reſiduum was a white earth, in quantity above three-fourths of the ſedative ſalt employed, and which, on examination, was found to be the ſiliceous earth; the liquor which paſſed over into the receiver being found to be the volatile phoſphoric acid. If, in this experiment, too much phoſphoric acid be added, a greaſy matter remains; and, if too little, a part of the ſedative ſalt will remain undecompoſed. In their attempts to compoſe borax, they combined phoſphoric acid with mineral alkali, the reſult of which was a compound reſembling borax in many reſpects. When expoſed to the fire it melts into a very fuſible glaſs, which has a mild taſte, and ſeems neutral, but on expoſure to the air, becomes moiſt and acid. On being ſaturated with alkali a ſecond time and vitrified, it again deliqueſces and becomes acid; and the more frequently this operation is repeated, the greater is the reſemblance it bears to borax. In this experiment they ſuppoſed that the alkali was decompoſed, and converted into an earth ſimilar to that of ſedative ſalt.

Experiments made to determine the nature of the ſedative ſalt.

With earthy ſubſtances the reſults were very remarkable. With earth of alum a cryſtallizable ſalt was obtained, which made paper burn with a green flame. Fixed alkali added to a ſolution of this ſalt precipitates an earth, and the ſalt then formed by cryſtallization reſembles borax in ſeveral properties.— In the dry way the earth of alum, with the phoſphoric acid, melts into a glaſs of the ſame fuſibility as that of borax, and like it is fixed in the fire. The ſolution of this glaſs did not cryſtallize. Common

clay

Acid of amber.

clay digested with phosphoric acid produces silky crystals resembling sedative salt. When dried with their mother-water, these give a clear glass, which when united with mineral alkali, has the taste of borax, smells in the same manner, and has the same effect upon metals. With lime, magnesia, and terra ponderosa, this acid produces fusible glasses, insoluble in water, and which communicate a green colour to flame. Earth of bones and selenite mixed with the acid give a white, hard, shining glass, like the best crystal, but fusible as the glass of borax, and which continued flexible after it had ceased to be red-hot. Two parts of gypsum, with one of phosphoric acid, gave a milk white glass fit for soldering metals and enameling. In these experiments, however, it must be remembered, that unless the heat be raised very quickly, the phosphoric acid will be evaporated before any fusion takes place.

VIII. *Acid of Amber.*

It was known to Agricola, that a particular kind of salt could be obtained from amber by distillation; but neither he, nor any succeeding chemist for some time ascertained its acid properties. On the contrary, some erred so far as to imagine that it was a volatile alkali; but, about the beginning of the present century, its acidity began to be generally acknowledged. This property indeed discovers itself by the taste, which is manifestly acid and empyreumatic, along with the peculiar flavour of amber. According to Scheele, also, the aqueous fluid which passes over in the distillation of amber, is an acid resembling vinegar both in taste and chemical properties; and which of consequence ought not to be confounded with the true acid of amber, which manifests qualities of a very different kind.

1494 Methods of purifying the salt of amber.

The properties of salt of amber can hardly be investigated until it has been purified; for which, of consequence, various methods have been proposed. Pott recommends crystallization, after having filtered the solution through cotton-wool, in order to retain the oil. Cartheuser attempts the purification by dissolving the impure salt in spirit of wine, then diluting with six times its quantity of water, and crystallizing the salt. Others recommend sublimation with common salt or sand, and Bergman with pure clay.

The salt of amber dissolves, by the assistance of heat, in nitrous and marine acids, and in the vitriolic without heat. In none of these combinations, however, does it either alter the dissolving acids, or suffer any alteration itself, except that it becomes whiter; with nitre it detonates and flies off; and if the quantity of salt of amber has been greater than that of nitre, the latter is alkalized. Stockar informs us, that it expels the marine acid from sal ammoniac, and sublimes before that salt; with which it does not form any union. When sublimed from common salt, it does not alter the latter in any other respect than giving it a darker colour. It precipitates calcareous earth from its solution in vinegar; and it decomposes sugar of lead; but the precipitate differs from plumbum corneum. It does not prevent the solution of lead in the acids of sea-salt and nitre; nor does it produce any sulphureous smell by calcination with charcoal. Hence it appears that it is neither a vitriolic, nitrous, nor marine acid; and M. Bourdelin must have been mistaken, when he affirms, that, after detonation of this salt with nitre, he obtained a residuum, which tasted like common salt, decrepitated in the fire, yielded crystals of a cubical form, precipitated silver and mercury from the nitrous acid; and thence concluded that it was the same with acid of sea-salt. It is very dear, as only about half an ounce can be obtained from a pound of amber.

Acid of amber and its combinations.

Acid of Amber combined.

1. *With fixed vegetable alkali.* By saturating salt of amber with the fixed vegetable alkali, and then slowly evaporating the solution, we obtain, according to Wenzel, a light deliquescent saline mass; but, according to Stockar, whose experiments are confirmed by those of Mr Keir, the solution abovementioned affords shining white transparent crystals of a triangular prismatic figure, with the terminating points truncated. These crystals readily dissolve in water, deliquesce in the air, and have a peculiarly bitter saline taste. In the fire they decrepitate, melt, and remain neutral; though Wenzel has observed, that with an intense heat they are decomposed and become alkaline. These crystals do not change aquafortis into aqua-regia; and though they precipitate both the solutions of lead and silver, the precipitates are neither plumbum corneum nor luna cornea.

2. *With Mineral alkali.* This combination produces long three-sided columnar crystals, intermixed with some that are foliated. These crystals do not deliquesce in the air, and have a saline, bitter, and smoky taste. They are less soluble than common salt, and melt with more difficulty than nitre. They do not become alkaline on burning coals, and, in their other properties, resemble the former.

3. *With volatile alkali.* This salt shoots into acicular crystals, having a sharp, saline, bitter, and cooling taste; when heated in a silver spoon, they melt and evaporate entirely; in close vessels they sublime. They do not precipitate solution of silver, nor change spirit of nitre into aqua-regis. A powerful antispasmodic remedy is prepared from rectified spirit of hartshorn and salt of amber.

4. *With lime.* This shoots into oblong pointed crystals, which do not deliquesce in the air, and are soluble with difficulty even in boiling water; nor, according to Mr Stockar de Neuforn, can they be decomposed by distillation either with acetous or marine acids. They detonate by distillation with nitrous acid; and are decomposed, either in the moist or dry way, by the vitriolic. When mixed with common sal ammoniac in the dry way, they suffer a decomposition; the succinated ammoniacal salt flying off and the combination of marine acid with lime remaining behind.

5. *With magnesia.* This yields a white, gummy, frothy, saline mass, which acquires a yellowish colour when dried by the fire; and, when cool, deliquates in the air. It is decomposed by alkalies and lime, as well as by the vitriolic acid.

6. *With clay.* By uniting the acid of amber with an edulcorated precipitate of alum with vegetable alkali, Wenzel obtained prismatic crystals, which could not be decomposed by alkalies.

7. *With silver.* The acid of amber has no effect on silver

Acid of amber and its combinations.

filver in its metallic ftate; but with its precipitate forms thin oblong cryftals, radiated and accumulated upon one another, from which the filver may be feparated by alkalies, by quickfilver, and by copper.

8. *With copper*. By a long digeftion of copper with acid of amber a green folution is obtained, which by mixture with common falt is rendered turbid, by vitriolic acid white, and lets fall a green precipitate on the addition of fixed alkali. Wenzel, however, could not obtain this precipitation by alkalies. His folution yielded groups of green cryftals, gave a cruft of copper to zinc, and was precipitated by liver of fulphur.

9. *With iron*. Wenzel diffolved a precipitate of this metal in acid of amber, and from the folution obtained fmall, brown, tranfparent, and ftellated cryftals. Zinc precipitated the metal, but not alkalies. From a flightly coloured folution of metallic iron, Pott obtained, by means of alkali, a white precipitate, which foon became yellow, and at length green, by pouring water upon it.

10. *With tin*. Acid of amber diffolves tin when precipitated by a fixed alkali; and the folution yields thin, broad, and foliated tranfparent cryftals. Alkalies throw down but little from this folution; liver of fulphur more; and lead, iron, or zinc, nothing.

11. *With lead*. Acid of amber whitens the furface of lead in its metallic ftate, but does not diffolve it; neither can lead be precipitated from its folutions in nitrous and marine acids by falt of amber, though this is denied by Pott. According to Stockar, however, it forms a white precipitate with fugar of lead. This metal precipitated by an alkali, and diffolved in acid of amber, forms long foliated cryftals lying upon one another; from the folution of which the lead may be precipitated by alkalies in the form of a grey powder, and by zinc in its metallic ftate.

12. *Zinc*, in its metallic ftate, is readily diffolved by the acid of amber; and by a combination with the precipitate formed by fixed alkali, we obtain long, flender, foliated cryftals, lying upon one another. The folution lets fall a white precipitate on the addition of fixed alkali; but this is denied by Stockar, who fays that volatile alkali produces a red precipitate.

13. *Bifmuth*. By means of heat, Stockar obtained a folution of this femimetal in acid of amber, which was decompofed by alkalies. Wenzel obtained, from a precipitate of bifmuth prepared by means of fixed alkali, fmall, flender, foliated, and yellow cryftals; which alkalies cannot decompofe, though black precipitates are thrown down by lead and zinc.

14. *Regulus of antimony*. Little or none of this femimetal, in its reguline form, is diffolved in the acid of amber; but it attacks the precipitate made with fixed alkali. This folution is very copioufly precipitated by liver of fulphur, but not by alkalies.

The combinations of this acid with gold, platina, nickel, arfenic, and manganefe, have either been found impracticable, or not yet attempted; all thofe above defcribed are non-deliquefcent, and part with their acid when expofed to the fire. The elective attractions of this acid, according to Bergman, are fingular, as it adheres more ftrongly, not only to terra ponderofa and lime, but to magnefia, than to fixed alkali.

On the origin of falt of amber, Mr Keir remarks, that "it deferves to be confidered as a pure and diftinct acid. No proofs have been adduced of its being a modification either of the marine or vegetable acids; as Mr Cornette and M. Hermbftadt have fuppofed. The former, having diftilled fpirit of falt with oil of lavender, obtained an acid which fmelled like falt of amber, but on examination was found to retain the properties of the muriatic acid. He alfo relates, that, when purifying a confiderable quantity of the falt of amber which he had prepared himfelf, fome fea-falt was feparated, which in the diftillation had arifen along with it. But this obfervation cannot be juftly applied to fhow any refemblance betwixt thefe two, any more than the fmell in the former cafe could fhow an analogy betwixt it and oil of lavender. This mixture of fea-falt with acid of amber, however, may readily explain the miftake of M. Bourdelin already mentioned. M. Weftrumb and M. Hermbftadt have both laboured in vain to convert the acid of amber into acids of fugar and tartar by frequent diftillations with fpirit of nitre; and their want of fuccefs confirms the account already given, that the acids of nitre and amber have no action upon each other, farther than that the former is phlogifticated or changed into red fumes, and the latter becomes whiter. Neverthelefs, if Mr Scheele's obfervation of the identity of the acid liquor, which comes over in the diftillation of amber with acetous acid, holds good, we fhall have the beft reafon yet given to afcribe the origin of this acid to the vegetable kingdom; and when we confider the very different properties that are affumed by the vegetable acids, which, however, are convertible into one another, no reafon can be drawn from the diverfity of its properties with thofe of other vegetable acids, againft its having a common origin with them. Indeed the natural hiftory of amber, its fimilarity to gums and refins, and its involved infects, afford other arguments in favour of the opinion.

1495 On the nature of the acid of amber.

IX. *Acid of* Arsenic.

1496 M. Pelletier's method of procuring the arfenical acid.

M. Berthollet remarks upon Mr Scheele's procefs, that during the operation a great quantity of dephlogifticated air is expelled from the acid. M. Pelletier has found another method of procuring the arfenical acid. He mixes common white arfenic with nitrous ammoniac, and diftils the mixture. At firft phlogifticated nitrous acid paffes over, then the volatile alkali, and laftly the arfenical acid remains in the retort in form of a vitreous mafs, which deliquefces into a very denfe acid liquor, reddening fyrup of violets, and effervefcing with alkalies. Mr Macquer had formerly defcribed this procefs, and obferved, that the nitrous acid paffes over firft, and then the volatile alkali; but was of opinion that the refiduum was nothing but arfenic. He mentions a detonation which took place in his experiment; but nothing of this kind was obferved by M. Pelletier: he only informs us, that the nitrous acid was driven over with great violence, while that of arfenic united with the volatile alkali. M. Berthollet, who has endeavoured to afcertain the weight gained by the converfion of fulphur, phofphorus, and arfenic, into acids, determines that of arfenic to be about one-ninth of the whole. At the fame time he obferves, that this additional weight does not difcover the whole weight of the air contained in the

Acid of molybdæna. the arsenic, as it had that necessary to convert it into calx before the operation of converting it into an acid was begun. On the other hand, M. Bergman asserts, that one-fifth of white arsenic is phlogiston, and that this calx is converted into acid merely by being deprived of its phlogiston. Thus the *facts* related by these two celebrated chemists differ enormously from one another; M. Berthollet affirming that the arsenic *gains* a ninth of its original weight in the process of acidification; and M. Bergman, that it *loses* a fifth part of the same. M. Berthollet endeavours to reconcile this, by supposing that Bergman had employed marine acid for the preparation of his arsenical acid, which is well known to cary off with it some part of most of those substances with which it is capable of combining; and to this he attributes the loss of weight in Bergman's process.

IX. *Acid of Molybdæna.*

1497 M. Pelletier's experiments. The opinion of M. Bergman concerning the metallic nature of the acid of molybdæna has obtained some confirmation from the experiments of M. Pelletier. He was not able indeed to obtain any regulus; but by means of oil alone he procured, by two hours vehement heat, a substance slightly agglutinated with a metallic lustre, containing small round grains of a grey metallic colour, very visible by the help of a magnifier. These he supposes to have been a true regulus of molybdæna; which he found to possess the following properties. 1. It is calcinable by fire into white calx. 2. It detonates with nitre, and the residuum is a calx of molybdæna united with the alkali of the nitre. 3. It is converted into a white calx by means of nitrous acid. 4. It yields inflammable air when treated with alkalies in the dry way, and forms peculiar compounds with them. 4. It forms regenerated molybdæna with sulphur. 6. It unites, and forms peculiar substances with metals. By uniting it with silver, iron, and copper, we have friable reguline masses; and refractory powders with lead and tin.

Our author, in consequence of his experiments, considers molybdæna as a metallic substance mineralized by sulphur; and the earth called the acid of molybdæna as a calx much dephlogisticated, which has retained part of the air contained in the nitrous acid. He observes likewise an analogy betwixt molybdæna and antimony in their chemical results. Both of them yield vitrifiable argentine flowers by similar operations, and both are changed into white earths by nitrous acid; but they differ in the two following respects. 1. The latter easily gives a fusible regulus; but the molybdæna seems to be the most refractory of all the semimetals. 2. The calx of regulus of antimony is soluble by alkalies in the moist way, but that of molybdæna is not.

X. *Acid of Tungsten or Wolfram.*

1498 Properties of tungsten. Mr Luyart, who has examined this mineral, gives the following account of it. 1. It is infusible by the blow-pipe, though the angles of the pieces into which it is broken are thereby rounded. 2. It effervesces with microcosmic salt, and melts before the blow-pipe into a reddish glass. 3. With borax it effervesces; and by the outward flame of the blow-pipe is changed into a reddish glass; by the internal flame into a greenish one. 4. Heated by itself in a crucible, it swelled, became spongy, semivitrified, and was attracted by the magnet. 5. With an equal part of nitre it detonated, or boiled up with a blue flame round the edges, and nitrous vapours arose. The mass was soluble in water, and let fall a white precipitate with acid. 5. It melted readily with fixed alkali, leaving a kind of black matter in the crucible, and a smaller quantity of lighter coloured substance on the filter. These residuums showed a mixture of iron and manganese. 6. With nitrous acid the filtered solution let fall a white precipitate, at first sweet, but afterwards bitterish and sharp, and which caused a disagreeable sensation in the throat; and the acidity of the solution of it was manifest, by its turning the tincture of turnsole red.

Having examined the substance by means of liquids in Mr Scheele's way, they obtained the same yellow powder which he had characterized as the acid of tungsten, along with a very small residuum, which appeared to contain a mixture of tin. Proceeding farther in the analysis, they found that wolfram is composed of manganese, calx of iron, the yellow matter called the *acid of tungsten* by Bergman and Scheele, with a very little mixture of quartz and tin, and which they considered as accidental.

1499 Of the yellow matter, called its acid by Mr Scheele. They now proceeded to examine the yellow matter, supposed by the two celebrated chemists just mentioned to be a simple acid salt, but which turned out very different on their inquiries. In order to procure a quantity of it, they melted six ounces of wolfram with as much vegetable alkali, dissolved the mixture in distilled water, filtrated the liquor, and evaporated it to dryness. Thus they obtained a white salt; upon which, when dry, they poured nitrous acid, and set it to boil in a sand-bath; by which operation it became yellow. They then decanted the liquor, pouring fresh acid upon the residuum; and repeated the operation a third time in order to deprive it of all the alkali. The remaining powder was then calcined in a cupelling furnace under a muffle, when it came out quite pure and yellow. The properties of it were then found to be as follow. 1. It is entirely insipid, and of the specific gravity of 6.12. 2. Before the blow-pipe, it continues yellow in the exterior flame even though put on charcoal; but grows black and swells, though it does not melt, in the internal flame. 3. In the internal flame it forms a blue transparent glass with microcosmic salt. The colour vanishes in the external flame, but appears again in the internal one; but by a continuance of this operation, it at last loses its colour so much that it cannot be recovered. 4. It effervesces, and forms a brownish yellow transparent glass with borax, which keeps its colour in both flames. 6. When triturated with water, it forms an emulsion which passes through filters without becoming clear, and continues a long time without any deposition. 7. It is insoluble in acids, but dissolves readily in the vegetable alkali both in the moist and dry way; though the produce has always an excess of alkali. 8. On adding nitrous acid in greater quantity than what is necessary to saturate this excess, a white powder falls, which is the same with the acid of tungsten discovered by Mr Scheele; but which Messrs Luyarts will

Acid of tungsten.

1500 No simple acid procurable from tungsten.

not allow to be a simple acid, though they admit that it contains one; and affirm, that its properties are various according to the circumstances of its precipitation. The properties of it, as described by them, are the following. 1. It is fusible before the blow-pipe, exhibiting the same phenomena as the yellow matter. 2. By calcination in a little pot or test, it emits the smell of nitrous acid, and turns yellow; but, on cooling, remains white, insipid, and insoluble; and this residuum melts by itself before the blow-pipe. 3. A yellow colour is produced either by vitriolic or marine acids; and the filtrated liquor affords a neutral salt with basis of fixed alkali, according to the nature of the acid employed. If the vitriolic acid is employed, and the operation performed in a retort, a quantity of nitrous acid passes over. 4. If, instead of pouring the acid on the salt, it be poured upon its solution, no precipitate will be formed, not even by making the liquor boil, if the quantity of acid is small; only the solution loses its sweet taste, and acquires more bitterness. On pouring on a large quantity of acid, and causing the liquor boil, a yellow precipitate is formed in every respect similar to the yellow matter so often mentioned. 5. This salt is completely dissolved by the boiling with vinegar. On leaving the solution to cool, a white waxy matter adheres to the sides of the vessel; which being washed and kneaded with the fingers, forms an adhesive mass like bird-lime, having a fat and greasy taste. By exposure to the air it acquires a dark grey colour, loses its adhesive property, and becomes bitter. It dissolves in water; and gives at first a sweet, then a bitter taste, making the tincture of turnsole red. 6. On evaporating the alkaline solution to dryness, pouring acetous acid upon the residuum, and then making it boil, the greater part of the residuum, was dissolved, and on cooling afforded feathery crystals. These when edulcorated had a sweet taste, though less strong than that of the former salt, which afterwards became bitter. Their solution turned blue paper red; was precipitated, and became like an emulsion with spirit of wine; and the residuum, which did not dissolve, appeared to be of the same nature. The crystals dissolved in fresh acetous acid, and communicated a blue colour to the acid; but this gradually disappeared on cooling, and a glutinous matter was deposited on the sides of the vessel, which had the properties of the former substance of that sort. If, in place of letting the solution cool, it should be kept boiling, the blue colour disappears, and nothing is precipitated. By adding spirit of wine when the liquor is almost evaporated to dryness, a white powder is precipitated; which after being edulcorated with fresh spirit of wine, tastes exceedingly bitter, and is very soluble in water. This solution, however, does not redden blue paper, nor make a blue with vinegar. With vitriolic acid its solution is blue; with vitriol of copper it forms a white precipitate. All these salts, by calcination, first become blue, then yellow, and lastly white. 7. On pouring a quantity of lime-water upon the solution of the precipitate formed by the nitrous acid, as well as on those obtained by the acetous acid, white precipitates were formed, all of which were a true regenerated tungsten. Having afterwards impregnated the liquors with fixed air, and boiled them in order to precipitate the lime more completely, they found in the solutions, after they were filtrated and evaporated to dryness, neutral salts formed of the precipitating acids, joined with alkaline and calcareous bases. This proved, that both alkali and acid were concerned in the precipitation. 8. On pouring the vitriolic solutions of iron, copper, and zinc, as well as that of marine mercurial salt, alum, and Prussian alkali, upon the solution of the precipitate formed by the nitrous acid, no precipitation ensues, and the acetous salts of copper and lead give white precipitates; but the Prussian alkali forms no precipitate with the acetous salts. Hence it appears that this salt is not a simple acid, but rather a salt composed of the yellow matter, fixed alkali, and the precipitating acid; and its composition appears more fully from the following experiments with the volatile alkali.

Acid of tungsten.

1. The yellow powder dissolves entirely in volatile alkali, but without any perfect saturation taking place; and the alkali always prevails. 2. The solution being set in a sand-bath, produced needle-like crystals, which had a sharp bitter taste, exciting a disagreeable sensation in the throat. Their solution turned the tincture of turnsole red, and the liquor from which they were crystallized had the same properties. 3. Having repeated this operation with different quantities of the same crystals, leaving some longer on the fire than others, solutions were obtained, whose acidity was in proportion to the time they had remained on the fire; but during the operation they all emitted the smell of volatile alkali. By calcination this alkali was entirely dissipated, and the residuum was a yellow powder, perfectly similar to that with which the operation was begun. On making use of a retort for the operation, the remaining powder was blue. 4. This salt precipitates the vitriolic salts of iron, copper, zinc, and alum, calcareous nitre, marine mercurial salt; the acetous salts of lead and copper; and with lime-water regenerates tungsten. The vitriolic acid decompounds it, and forms a blue precipitate; the nitrous and marine acids produce a yellow; but no precipitate is occasioned by the Prussian alkali.

Having poured nitrous acid upon a portion of the solution with excess of alkali, a white powder was precipitated, which, after edulcoration, had a taste at first sweet, but afterwards sharp and bitter, and its solution turned the tincture of turnsole red. This, on examination, appeared to be a triple salt formed of the yellow powder, volatile alkali, and the precipitating acid.

1501 A kind of semimetal procurable from tungsten.

The following experiments realize the conjecture of Bergman, that the acid of tungsten is the basis of a particular semimetal.

1. "Having kept 100 grains of the yellow powder (says M. Luyart) in a Zamora crucible well covered, and set the whole in a strong fire for half an hour, it became a spongy mass of a bluish black colour, the surface of which was crystallized into fine points, like plumose antimony, and the inside compact, and of the same colour. It was too hard to be broken in pieces by the fingers; and, when ground, was reduced to a dark blue colour.

2. "Having mixed 100 grains of the same powder with 100 of sulphur, and put the mixture in a Zamora crucible on a strong fire for a quarter of an hour, it came out a dark-blue mass, which was easily broke by

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Acid of tungsten.

the fingers; and the inside presented a crystallization like needles as the last, but transparent, and of the colour of a dark lapis lazuli. This mass weighed 42 grains, and when placed on burning coals yielded no smell of sulphur.

3. "Having put another 100 grains of this powder into a Zamora crucible, provided with charcoal, and well covered, and placed it in a strong fire, where it remained an hour and a half, we found, on breaking the crucible after it was cool (A), a button, which fell to powder between the fingers. Its colour was dark brown; and on examining it with a glass, there was seen a congeries of metallic globules, among which some were the bigness of a pin's head, and when broke had a metallic appearance at the fracture in colour like steel. It weighed 60 grains: of course there was a diminution of 49. Its specific gravity was 17.6. Having calcined part of it, it became yellow, with [illegible] increase of weight. Having put one portion of this substance powdered, in digestion with the vitriolic acid, and another with the marine acid, neither of them suffered more diminution than [illegible] of their weight; then decanting the liquor, and examining the powder with a glass, the grains were still perceived of a metallic aspect. Both the acid liquors gave a blue precipitate with the Prussian alkali, which let us know that the small diminution proceeded from a portion of iron which the button had undoubtedly got from the powder of the charcoal in which it had been set. The nitrous acid, and aqua-regia extracted likewise from two other portions the ferruginous part; but besides, they converted them into yellow powder, perfectly similar to that which he used in this operation.

4. "Having put 100 grains of gold and fifty of the yellow powder in a Zamora crucible furnished with charcoal, and kept in a strong fire for three quarters of an hour, there came out a yellow button which crumbled in pieces between the fingers; the inside of which showed grains of gold, separated from others of a dark-brown colour. This demonstrated there had not been a perfect fusion and likewise that this substance was more refractory with gold, since the heat which it endured was more than sufficient to have melted it. The button weighed 139 grains; of course there was a diminution of 11 grains. Having put this button with lead in the cupelling furnace, the gold remained pure in the cupel; but this operation was attended with considerable difficulty.

5. "Having made a mixture of platina and yellow powder in the preceding proportions, and exposed it to a strong fire, with the same circumstances, for an hour and a quarter, it produced a button which crumbled with ease between the fingers, and in which the grains of platina were observed to be more white than usual, and some of them changed sensibly in their figure. This button weighed 140 grains, and of consequence there had been a loss of 10 grains. When calcined, it took a yellow colour, with very little increase of weight; and after washing it to separate the platina, there remained 118 grains of a black colour. Having placed this portion again to calcine over a strong fire in a muffle, it suffered no sensible alteration in weight or colour; for it neither grew yellow, nor took the brown colour of the platina, but kept the same blackness as before it was calcined. It must be attended to, that in the washings there was not so much care taken to collect all the platina as to deprive it of the yellow colour, and for this reason the water carried off part of the fine black powder: and consequently the increase which the platina preserved, after being washed and calcined the second time, ought to be computed more than the 18 grains which it showed by its weight.

"Having mixed the yellow powder with other metals in the preceding proportions, and treated them in the same manner, the result was as follows:

6. "With silver it formed a button of a whitish-brown colour, something spongy, which with a few strokes of a hammer extended itself easily, but on continuing them split in pieces. This button weighed 142 grains, and is the most perfect mixture we have obtained, except that with iron.

7. "With copper it gave a button of a copperish red, which approached to a dark brown, was spongy, and pretty ductile, and weighed 133 grains.

8. "With crude or cast-iron, of a white quality, it gives a perfect button, the fracture of which was compact, and of a whitish brown colour: it was hard, harsh, and weighed 137 grains.

9. "With lead it formed a button of a dull dark-brown, with very little lustre; spongy, very ductile, and splitting into leaves when hammered: it weighed 127 grains.

10. "The button formed with tin was of a lighter brown than the last, very spongy, somewhat ductile, and weighed 138 grains.

11. "That with antimony was of a dark-brown colour, shining, something spongy, harsh, and broke in pieces easily: it weighed 108 grains.

12. "That of bismuth presented a fracture, which, when seen in one light, was of a dark-brown colour, with the lustre of a metal; and in another appeared like earth, without any lustre: but in both cases one could distinguish an infinity of little holes over the whole mass. This button was pretty hard, harsh, and weighed 68 grains.

13. "With manganese it gave a button of a dark bluish-brown colour and earthy aspect; and on examining the internal part of it with a lens, it resembled impure drops of iron: it weighed 107 grains."

XI. *Acid of Ants.*

Etmuller is among the first authors who mentions the existence of this acid, and speaks of obtaining it by distillation. Nothing of its properties, however, was known, until Margraaf undertook to examine it; of whose experiments we have an account in the Memoirs of the Berlin Academy for 1749. Since his time a number of chemists have prosecuted the subject to

(A) "The first time we made this experiment, we broke the crucible without letting it cool entirely; and as soon as the matter was in contact with the air, it took fire, and its dark brown colour turned instantly yellow."

Acid of ants.

to a considerably greater length; but Mr Keir prefers the researches of Arvidson, Bucholtz, and Hermbstadt, to the rest.

The acid in question is a natural juice which the insects discharge when irritated, and which is very pungent to the smell as well as taste. Thus it may instantly be perceived on turning up an ant-hill in spring or summer. The *formicæ rubræ* of Linnæus are those insects which have hitherto supplied this acid. Mr Arvidson advises to collect them in the months of June and July, by laying some smooth sticks upon an ant-hill; which being then disturbed, the ants will run upon the sticks in great numbers, and may then be swept off into a vessel containing water until it be full. Hermbstadt collects them in the same manner, but into a dry bottle, to avoid the evaporation of the superfluous liquid. Bucholtz having moistened the inside of a narrow necked glass bottle with honey and water, sunk it into a disturbed ant-hill until the mouth was level with the ground; on which the insects, allured by the smell of the honey, went into the bottle, and could not get out.

1502 Different methods of obtaining this acid.

For obtaining the acid, Margraaf employed distillation, with the addition of fresh water. Thus he obtained, from 24 ounces of fresh ants, 11 ounces and two drachms of acid, some volatile alkali, empyreumatic oil, and a residuum containing earth and fixed salt. Arvidson made use of two methods: One consisted in distilling the ants when dry; from a pound of which, in this state, he obtained eight ounces of acid besides the empyreumatic oil. His other method was to inclose, in a piece of linen, the ants previously cleaned by washing in water, then to pour boiling water upon them, and to repeat the operation until it could extract no more acid; which is then obtained by squeezing the linen, mixing all the liquors, and filtering them. Thus from a pound of ants he obtained a quart of acid liquor, which tasted like vinegar, but was specifically heavier. By distillation Hermbstadt obtained from a pound of dry ants ten ounces and a half of yellow empyreumatic liquor, which did not taste more strongly acid than the spirit obtained by distilling wood, on which swam three drachms of a brown fetid oil, in all respects like that of hartshorn. In the retort was left a black residuum weighing one ounce six drachms, which exhibited signs of containing volatile alkali. By distilling a pound of ants with three of water, according to Mr Margraaf's method, he obtained an acid liquor and some oil in the receiver; and from the surface of that which remained undistilled, he collected a drachm and an half of fat oil.

The specific gravity of the acid liquor obtained by Mr Arvidson's maceration was 1,0011; that of the same liquor, when distilled, 1.0075; and of the acid concentrated by freezing, 1.0453. According to Bucholtz, the acid liquor thus obtained by maceration did not grow in the least mouldy in the space of four weeks; during which it was allowed to rest in order to free itself perfectly from the impurities it contained. Mr Hermbstadt, however, prefers Margraaf's method of distillation to that of Arvidson's macerations, not only as being a more perfect analysis, but as less laborious; though he finds fault also with Margraaf's method, as diluting the acid too much, and altering it so that it has not the smell of living ants. He totally disapproves of the method of distilling dried ants, as the acid is thus in a great measure decomposed, and the remainder united with much oil. To avoid all these inconveniences, he contrived another method, namely, to express the juice of the insects; by which means he obtained at once a concentrated liquor fit for distillation. In this way he obtained from two pounds of dried ants 21 ounces and two drachms of juice, which had a pungent and highly acid smell, resembling the vapours of fluor acid; in taste resembling concentrated vinegar and acid of tartar; to which last it might be compared for strength of acidity. By distilling eight ounces of this expressed liquor, he obtained six ounces and a half of clear acid, equal in strength to a very concentrated vinegar.

1503 Properties of the pure acid.

The acid, when thus procured in purity, has a pungent, not unpleasant smell, a sharp, caustic taste, and an agreeable acidity. It reddens blue paper, syrup of violets, and litmus; blackens the vitriolic acid, and converts part of it into a sulphureous vapour. It is also decomposed by distillation with nitrous acid. Spirit of salt likewise, when dephlogisticated, decomposes it, but not in its ordinary state. It does not form sulphur by an union with phlogiston, but produces inflammable vapours by dissolving iron or zinc. By the assistance of a gentle heat it dissolves soot, but oils with much more difficulty, and powder of charcoal not at all. It does not unite with vitriolic ether; but in distilling a mixture of this acid with spirit of wine, Mr Arvidson saw some traces of an ether, and M. Bucholtz perfectly succeeded in making an ether by means of it. It unites with fixed alkali, forming, according to M. Margraaf, a neutral salt, consisting of oblong deliquescent crystals, from which very little acid could be procured by distillation *per se*, but on adding concentrated oil of vitriol, a very strong and pure acid was obtained; from a mixture of which with spirit of wine, M. Bucholtz readily obtained a true ether. With mineral alkali it forms deliquescent foliated crystals of a saline bitter taste, and soluble in twice their weight of water. With volatile alkali it forms an ammoniacal liquor; which, according to Arvidson, cannot be brought into a dry state; but Mr Arvidson says he has obtained crystals from it, though very thin and deliquescent. Margraaf obtained dry crystals by uniting this acid, with chalk or coral; and Arvidson observes that this salt is transparent, cubical, or rhomboidal, nondeliquescent, soluble in eight parts of water, of a bitter taste, and insoluble in spirit of wine. No acid can be obtained from it by distillation *per se*. From a solution of magnesia in this acid, Mr Arvidson obtained some saline particles by deposition, and afterwards an efflorescence of transparent salt rising round a saline mass. This salt had scarcely any taste, was soluble in 13 parts of water, and insoluble in spirit of wine. With ponderous earth the acid formed a cluster of bitter needle-like crystals, which did not deliquesce, were soluble in four times their quantity of water, insoluble in spirit of wine, and when burnt gave out a smell like that of burnt sugar, leaving a coal which effervesced with acid. It unites with difficulty to the earth of alum, and can scarcely be saturated with it. It does not precipitate silver, lead, or mercury, from their solution in nitrous acid; whence it seems to have no affinity to the ma-

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Acid of apples.

rine acid: and as it does not precipitate lime from the marine acid, it seems to have as little with the vitriolic.

1504 Has an affinity with the acetous acid.

From his experiments, however, Margraaf concluded, that the acid of ants, in many respects, though not in all, has a great affinity with the acetous acid. From this it is distinguished by forming different compounds, and likewise by having different affinities. It dislodges the acetous acid also in all instances, and the arsenical acid from cobalt and nickel. It has a greater attraction for fixed alkalies than for lime.

1505 Its effects on metals.

As a solvent it acts but weakly upon copper; not at all, or very little, on silver, lead, tin, regulus of antimony, or bismuth, but strongly on iron or zinc. It dissolves, however, the calces of copper, silver, zinc, and lead, without affecting those of tin, regulus of antimony, or bismuth. The calx of quicksilver, according to Margraaf, is revived by it. According to Arvidson, it crystallizes with iron, zinc, or lead; does not act upon the regulus of antimony, of arsenic, cobalt, or nickel; though it dissolves their calces as well as the precipitate of manganese. Gold, mercury, and the calx of platina, are not affected by it; but it crystallizes with those of copper, silver, lead, bismuth, and mercury.

1506 Acid procured from various insects.

In its strength of attraction, the acid of ants exceeds those of vinegar, borax, and the volatile sulphureous and nitrous acids. Insects armed with stings, as bees, wasps, and hornets, are likewise said to discharge a very acid juice when irritated; and Mr Bonnet has observed a very strong acid ejected by a caterpillar which he distinguishes by the name of *grande chenille du saule a queu fourchue*. None of these, however, have been as yet particularly examined.

XII. *Acid of Apples.*

1507 Acid of citrons how procured.

That the juices of unripe fruits contain some kind of acid has been universally known, and attempts to investigate the nature of it have been made some time ago: but it is to Mr Scheele that we owe the discovery of the particular acid now treated of. He had observed that the juice of citrons contained a particular acid; which, by being united with lime, formed a salt very insoluble in water; and which therefore by means of lime could be readily separated from the mucilaginous part of the juice. By adding vitriolic acid to this compound of lime with the acid juice, almost in the same manner in which he used to procure the acid of tartar, the lime was again separated, and the pure acid of citrons obtained. Proceeding in the same manner with other fruit, he found that an acid, agreeing in every respect with that of citrons, could be procured from the juice of the *ribes grossularia*. Examining the juice which remained after the separation of the former acid from the citrons, he found that it still contained another acid; which being saturated with more calcareous earth, formed a salt

1508 Another acid procured from the juice of fruits.

easily soluble in water, and therefore remained suspended in the juice. To separate this new salt, he added some spirit of wine, by which the salt was precipitated; but finding that it still contained much gummy matter, he judged that it would be proper to attempt a separation of this gum before he precipitated the salt. For this purpose he evaporated some of the juice of the ribes grossularia to the consistence of honey, dissolving the mass afterwards in spirit of wine. Thus the acids, which are soluble in the spirit, were easily separated by filtration from the insoluble gum. He then evaporated the spirit, adding to the remainder twice its quantity of water, with as much chalk as was necessary for the saturation. The liquor was next boiled for two minutes; during which the insoluble salt was precipitated, and the liquor separated from it by filtration contained the solution of chalk in the new acid. To this solution he added spirit of wine, which again precipitated the salt, while some saponaceous and saccharine matters remained dissolved in the spirit.

1509 Its properties.

Having thus at last obtained the salt in a state of purity, he proceeded to examine its nature; and found, 1. That some of it, spread on his nail, soon dried, and assumed the appearance of varnish. 2. It was very soluble in water, and turned litmus red. 3. When the solution had stood some days exposed to air, it was found to have deposited a number of small crystals, which could only be dissolved by a quantity of boiling water; and this salt was also found to be completely neutralized, so that, it yielded its calcareous earth to a fixed alkali. 4. The salt was decomposed by heating *per se* in a crucible, and left a mild calcareous earth. 5. The acid was separated from the earth by adding oil of vitriol diluted with water until gypsum was no longer precipitated, and the new acid was left disengaged, so that it could be separated by filtration. 6. By this operation, however, all the lime was not precipitated; so that the separation of the acid was not complete. 7. He observed that the acid had a greater attraction for lead than for lime; and therefore made use of the method he had formerly discovered for separating the acid of sorrel. To the acid he added a solution of sugar of lead; by which the acid was precipitated along with the lead, and the vinegar was left

1510 How procured in perfect purity.

in the liquor. To this precipitate, cleaned from the acetous acid by filtration, he added vitriolic acid, which expelled the weaker vegetable one, and thus left it quite pure and free from any heterogeneous mixture.

The juice of apples, either ripe or unripe, was found to contain no acid of citrons, but a large quantity of the new acid; which, being thus alone, he could more easily procure by a single operation. The best method of procuring this he found to be by saturating the juice of the apples with a solution of fixed vegetable alkali, and pouring a solution of sugar of lead to that of the salt just mentioned. The effect of this was a double decomposition, and a precipitate of lead combined with the new acid. To the edulcorated precipitate he then added a dilute vitriolic acid till he could no longer perceive any sweet taste in the liquor; for the first portions of the vitriolic acid dissolve a part of the calx of lead, and impart a sweetish taste to the liquor, which is sensible, notwithstanding its acidity; but when the quantity of vitriolic acid is sufficient to saturate the whole of the calx, all the metal falls to the bottom, and the sweetness ceases; so that the acid is at once obtained pure.

1511 Properties of it when obtained from the juice of apples.

The acid of apples is possessed of the following properties. 1. It cannot be crystallized, but always remains in a liquid state; or, if much evaporated, attracts the moisture of the air. 2. With fixed alkalies

Acid of apples.

of all kinds it forms deliquefcent falts. 3. With calcareous earth it forms fmall irregularly fhaped cryftals, which cannot be diffolved but in a large quantity of boiling water; but if the acid is fuperabundant, the falt readily diffolves in lime-water. 4. It is effected by ponderous, earth in the fame manner as by lime. 5. Earth of alum forms, with the acid of apples, a falt not very foluble in water. 6. With magnefia the acid forms a deliquefcent falt. 7. Iron is diffolved into a brown liquor, which does not cryftallize. 8. The folution of zinc affords fine cryftals. 9. On other metals it has no remarkable effects. From the acid of citrons it differs. 1. The acid of citrons fhoots into fine cryftals. 2. The acid of apples can be eafily converted into that of fugar, which Mr Scheele could not accomplifh with that of citrons; though Mr Weftrumb has fince done it. 3. The falt formed with the citron acid and lime is almoft infoluble in water; but that with acid of apples and lime is eafily foluble. 4. Acid of apples precipitates mercury, lead, and filver from their folution in nitrous acid, and likewife the folution of gold, when diluted with water; but the acid of citrons does not alter any of thefe folutions. 5. The acid of citrons feem to have a greater attraction for lime than that of apples.

1512 Produced from fugar by means of nitrous acid.

It is remarkable that this acid is the firft produced in the procefs for making fugar. If a diluted acid of nitre be drawn off from a quantity of fugar until the mixture becomes a little brown, which is a fign that all the nitrous acid is evaporated, the fyrup will be found to have acquired a fourifh tafte; and if, by means of lime, we next feparate all the acid of fugar, another will ftill remain, which diffolves the calcareous earth. When this acid is faturated with chalk, and the folution filtered and mixed with fpirit of wine, a coagulation takes place. On feparating the curdled part by means of a fieve, diffolving it in water, and then adding fome vinegar of lead, the calx of lead will be precipitated; and if the new acid is then feparated from the metal by means of diluted oil of vitriol, it will be found to poffefs all the properties of the acid of apples, and is indeed the fame. The fpirit of wine, which has been employed to precipitate the calcareous falt, leaves on evaporation a refiduum of a bitter tafte, very deliquefcent, and fimilar to the faponaceous extract of the citron.

1513 Experiments with nitrous acid on various fubftances.

The following are the refults of Mr Scheele's experiments with the nitrous acid upon different fubftances. 1. From gum arabic he obtained both the acid of apples and of fugar. 2. The fame products were obtained from manna. 3. From fugar of milk he obtained not only its own peculiar acid, but thofe of apples and fugar. 4. Gum tragacanth, during its folution in nitrous acids, lets fall a white powder, which was found to be the acid of the fugar of milk. This gum contained alfo the acid of apples and of fugar, and a falt formed from lime and the acid of apples. 5. Starch left an undiffolved matter; which being feparated by filtration, and wafhed, refembled a thick oil like tallow, which, however, was found to be very foluble in fpirit of wine. By diftillation he obtained from this oily matter an acid fimilar to that of vinegar, and an oil which has the fmell of tallow, and congeals by cold; and, befides thefe fubftances, he found that ftarch yielded the acids of apples and fugar. 6. From the root of falep he obtained the acid of apples, with a large quantity of calcareous faccharine falt. 7. Extract of aloes indicated the exiftence of the acids of fugar and apples, and loft the greateft part of its bitter tafte. During the digeftion a refinous matter was feparated, which fmelled like flowers of benzoin, and took fire on being heated in a retort. 8. Extract of colocynth was converted by nitrous acid into a refinous fubftance, and fhowed fome figns of containing acid of fugar. 9. The extracts of Peruvian bark and of the other plants examined by Mr Scheele, gave both the acids of apples and fugar. 10. Thefe two acids were likewife obtained from an infufion of roafted coffee, evaporated to the confiftence of a fyrup. 11. The fame products were obtained from an extract of rhubarb, which yielded alfo a refinous matter. 12. Juice of poppies afforded the fame refults. 13. Extract of galls did the fame. 14. The effential oils afforded little or none of the acids; but the oil of parfley-feeds feemed to be entirely convertible into them. 15. With a very concentrated acid he was able alfo to decompofe animal fubftances. From glue he thus obtained fine cryftals of acid of fugar, and afterwards acid of apples. Ifinglafs, whites and yolks of eggs, afforded the fame products. From all thefe fubftances, efpecially the laft, a fat matter was feparated: but it was remarkable that the gas, expelled during the procefs, was compofed of a little fixed air, a great quantity of phlogifticated air, and very little nitrous air, whereas no phlogifticated air is obtained in the ufual procefs for preparing acid of fugar. He obferved alfo that in the procefs for this acid, a fmall quantity of vinegar is found in the receiver. He could not obtain the acid of fugar from the faponaceous extract of urine; but got inftead of it a falt, which, when completely purified, refembled exactly the flowers of benzoin. The fame falt is precipitated in abundance by adding to the extract of urine a little vitriolic or marine acid; and Mr Scheele had already remarked that the fame falt is obtained in the diftillation of fugar of milk.

1514 Of the nature of this acid.

From the various experiments which have been made on this acid, it feems, according to Mr Keir, to be in an intermediate ftate betwixt acid of tartar and acid of fugar. This, however, ought not to prevent it from being accounted a feparate and diftinct acid, otherwife we might confound all the vegetable acids with one another. It approaches more nearly to the nature of acid of milk than of any other. From this alfo, however, it is diftinguifhed, becaufe the falt formed by the union of acid of milk with lime is foluble in fpirit of wine, but not that from lime and the acid of apples. According to Mr Hermbftadt, if three parts of fmoking nitrous acid be abftracted from one part of fugar, and if the brown acid mafs which remains in the retort be diluted with fix times its weight of diftilled water, and faturated with chalk, two compounds will be formed; one confifting of the acids of tartar and lime, which will precipitate; and the other of lime and the acid of apples, which will remain fufpended. If the calcareous earth be precipitated from this latter folution by adding acid of fugar, a pure acid of apples will be left in the liquor:

and

Acetous acid. and he further informs us, that this acid of apples may be changed entirely into those of sugar and vinegar, by means of strong nitrous acid.

XIII. *Acetous Acid.*

1515 How to crystallize spiritus Mindereri. It is generally believed, that the combination of this acid with volatile alkali is altogether incapable of crystallization; but Scheffer and Morveau inform us, that it may be reduced into small needle-shaped crystals, when the spiritus Mindereri is evaporated to the consistence of a syrup, and left exposed to the cold. The salt has a very sharp and burning taste, but a considerable quantity is lost during the evaporation. Westendorf, by adding his concentrated vinegar to volatile alkali, obtained a transparent liquor which did not crystallize. By distillation it went over intirely into the receiver, leaving a white spot on the retort. A saline transparent mass, however, appeared in the receiver under the clear fluid. On separating it from the liquid, and exposing it to a gentle heat, it melted, threw out white vapours, and in a few minutes shot into sharp crystals resembling nitre. These remained unchanged in the cold; but when melted with a gentle warmth, smoked and evaporated. Their taste was first sharp and then sweet.

1516 Salt from the acetous acid combined with calcareous earth. The salt formed by uniting acetous acid with calcareous earth has a sharp bitter taste, and shoots into crystals somewhat resembling ears of corn. These do not deliquate in the air, unless the acid has been superabundant. They are decomposed by distillation *per se*, the acid coming over in white inflammable vapours smelling like acetous ether, somewhat empyreumatic, and condensing into a reddish brown liquor. By rectification this liquor becomes very volatile and inflammable; on adding water, it acquires a milky appearance, and drops of oil seem to swim upon the surface; a reddish brown liquor, with a thick black oil, remain after rectification in the retort. On mixing this calcareous salt with that of Glauber, a double decomposition takes place; we have a gypsum and the mineral alkali combined with acetous acid. By calcination, the mineral alkali may be obtained from this salt in a state of purity. This acetous calcareous salt is not soluble in spirit of wine.

1517 With magnesia. On saturating this acid with magnesia, and evaporating the liquor, we obtain a viscid saline mass like mucilage of gum arabic, which does not shoot into crystals, but deliquesces in the air. It has a sweetish taste at first, but is afterwards bitter. It is soluble in spirit of wine, and parts with its acid by distillation without addition.

1518 With zinc. Acetous acid dissolves zinc both in its metallic and calciform state, and even when mixed with other metals. By concentrated vinegar the zinc is dissolved with great heat, sulphureous smell, and exhalation of inflammable matter. By this union we obtain a congealed mass, which on dilution with water shoots into oblong sharp crystals at the first crystallization, and afterwards into crystals of a stellated form. From this liquor indeed crystals of various forms have been obtained by different chemists. Monnet obtained from it a pearl-coloured salt in friable talky crystals; which when thrown on the coals, fulminated a little at first, and gave a bluish flame, and then melted, letting its acid escape, while a yellow calx remained. Hellot informs us, that this salt by distillation *per se* in water, affords an inflammable liquor, and an oil at first yellow and then green, with white flowers burning with a blue flame. Westendorf obtained no oil in this distillation, but some acetous acid; a sweet-tasted empyreumatic liquor impregnated with zinc; sweet flowers, or sublimate, soluble in water, and burning with a green flame. On applying a stronger heat, the zinc was sublimed in its metallic form, leaving a spongy coal at the bottom of the retort. The solution gives a green colour to syrup of violets, lets fall a white precipitate on the addition of alkalies or an infusion of galls. It is not precipitated by common salt, vitriolated tartar, vitriolic or marine acids, blue vitriol, or corrosive sublimate; but forms a red precipitate when added to a solution of gold; a white precipitate with solution of silver; a crystalline pearly precipitate with solution of mercury; and crystalline precipitates with solutions of bismuth and tin. According to Bergman, it is decomposed by acid of arsenic.

1519 Its phenomena with arsenic. Though regulus of arsenic is not soluble in this acid, its calx may be dissolved either in common or distilled vinegar. M. Cadet obtained a smoking liquor by distillation from a mixture of white arsenic and terra foliata tartari. This experiment has been repeated by the chemists of Dijon, and attended with the following curious circumstances. "We digested (say they), in a sand-bath, five ounces of distilled vinegar on white pulverized arsenic; the filtrated liquor was covered, during evaporation, with a white saline crust. Of this substance were formed 150 grains; on which fixed alkali appeared to have no effect, and which was at first considered as pure arsenic. However, a cat, which had swallowed 72 grains of it, was only affected with vomitings that day and the next, and afterwards perfectly recovered. A similar dose was given to a little dog; but as he ran away, the effect it had upon him could not be discovered; but he returned afterwards in good health, and never showed any uneasiness: whence it may be concluded, that vinegar is in some measure an antidote against the pernicious qualities of arsenic.

1520 Vinegar supposed to be an antidote against arsenic.

"On redissolving this saline crust in pure water, filtering and mixing it with liquid alkali, an irregularly crystallized salt was formed in it after a few days standing. By this salt a yellow precipitate was thrown down from the nitrous solution of silver; whereas the solution of arsenic and terra foliata tartari threw down a white one.

"Equal parts of terra foliata tartari and arsenic, distilled in a retort, gave first a small quantity of limpid liquor with a penetrating smell of garlic, and which had the property of reddening syrup of violets; while solution of arsenic in water turns that syrup green. The vinegar which now arose was not saturated when arsenic, but effervesced strongly with fixed alkali, with which it became turbid, but did not let fall any precipitate. On changing the receiver, there came over a reddish brown liquor, accompanied with thick vapours, diffusing an intolerable smell, in which that of arsenic could scarcely be distinguished. On continuing the operation, a black powder sublimed into the neck of the

Acetous acid.

the retort, together with a little arsenic in its metallic form, and a matter which took fire by a lighted candle like sulphur.

"The red liquor still preserved its property of smoking though cold; diffusing at the same time its peculiar and abominable fetor, from which the apartment could scarcely be freed in several days. This liquor does not alter the colour of syrup of violets, but effervesces slightly with fixed alkali, letting fall at the same time a yellow precipitate, which, however, disappeared on an attempt to separate it by filtration.

1521 Curious phosphoric liquor.

"M. Cadet had observed, that the smoking liquor of arsenic did not kindle at the approach of a lighted candle; but that, on pouring it from the receiver into another vessel, it had kindled the fat lute with which the junctures had been closed, and which had been dried during the operation: but we, being desirous of examining more fully the nature of the red liquor which collects at the bottom, and has the appearance of oil, having decanted that which swims on the top, and poured the remainder on a filter of paper, before many drops had passed, there arose a thick smoke forming a column from the vessel to the ceiling; a slight ebullition was perceived at the sides of the vessel, and a beautiful rose-coloured flame appeared for a few moments. The paper filter was burnt at one side, but most of it was only blackened. After the flame was extinguished, a fat reddish matter remained: which being melted on burning coals, swelled considerably, emitting a white flame. It then sunk, and left on the coal a black spot, which could not be effaced but by the most vehement fire.

"At the time these observations were made, the liquor had been distilled for three weeks, and the bottle frequently opened. The inflammability could not proceed from the concentration of the vinegar: for the rose-colour of the flame, the precipitation of the sublimate, and the fixity of the spot remaining on the coal, evidently showed that the two substances were in a state of combination; which is also further evinced by the loss of the inflammable property when the liquor was decomposed by fixed alkali.—The smell of the liquor, however, though so intolerably fetid, was attended with no other inconvenience than a disagreeable sensation in the throat, which further strengthens the suspicion that vinegar is an antidote against arsenic.

"The saline brown mass remaining in the retort was partly dissolved by hot water; and the filtrated lixivium was very limpid, but emitted the peculiar smell of the phosphoric liquor. By evaporation it yielded a salt which did not deliquesce in the air, of an irregular shape; and which being put on burning coals, did not smell sensibly of arsenic; lost its water of crystallization; and became mealy and white without being dissipated by heat. On exposing the residuum to the air, it was found next day resolved into a liquor; whence it is probable that most of it was composed of crystallized alkali, having received from the decomposition of the vinegar as much fixed air as was necessary for its crystallization."

1522 Effect of the acetous acid on mercury.

This acid does not act upon mercury in its metallic state, but dissolves the mercurial calces, as red precipitate, turbith mineral, and the precipitate formed by adding fixed alkali to a solution of mercury in nitrous acid; with all which it forms white, shining, scaly crystals, like those of sedative salt.

1523 On silver.

Vinegar does not act upon silver in its metallic state, but readily dissolves the yellow calces precipitated from its solution in nitrous acid by microcosmic salt and volatile alkali. By the help of a boiling heat also it very copiously dissolves the precipitate obtained by means of a fixed alkali. The last mentioned solution yields shining, oblong, needle-shaped, crystals, which are changed to a calx by means of several acids, especially the muriatic. The silver is thrown down in its metalic form by zinc, iron, tin, copper, and quicksilver.

1524 On gold.

Though the acetous acid has no effect upon gold in its metallic state, yet a solution of this metal is decomposed by crude vinegar, which produces both a metallic precipitate and dark violet-coloured powder. Distilled vinegar throws down the gold in its metallic form. The precipitate by fixed alkali digested with acetous acid is of a purple colour. This, as well as fulminating gold, is dissolved by Westendorff's concentrated vinegar; the fulminating gold very easily. The solution is of a yellow colour; and with volatile alkali affords a yellow precipitate; with lixivium sanguinis, a blue one; both of which fulminate. The dry salt of gold dissolves in the acetous acid, and produces oblong yellow crystals.

1525 On inflammable substances.

This acid has no effect on fat oils, farther than that when distilled together, some mixture takes place, as the Abbé Rozier has observed. Neither does distilled vinegar act upon essential oils, though M. Westendorff's distilled vinegar dissolved about a sixth part of oil of rosemary, and about half its weight of camphor. The latter solution was inflammable, and let fall the camphor on the addition of water. The acid dissolves all the true gums, and some of those called gum-resins, after being long digested with them. By long boiling, Boerhaave observes, that it dissolves the bones, cartilages, flesh, and ligaments of animals.

1526 Concentration of the acetous acid.

The concentration of this acid may be effected by combining it with alkalies, earths, and metals. By combining it with copper, and then crystallizing and distilling the compound, we obtain the acid in the highest state of concentration in which it is usually met with. To produce this strong acid, we have only to distill verdegris, or rather its crystals in a retort. The operation must be begun by a very gentle fire, which brings over an aqueous liquor. This is to be set aside, in order to procure the more concentrated acid, which comes over with a stronger fire. On changing the receiver, and augmenting the heat, we obtain a very strong acid which comes over partly in drops, and partly in white vapours. It is called radical vinegar, or sometimes spirit of Venus, and has a very pungent smell, almost as suffocating as that of volatile sulphureous acid. As the last portions of it adhere pretty strongly to the metal, we are obliged to raise the heat to such a degree as to make the retort quite red in order perfectly to separate them. Hence some part of the metal is raised along with the acid, which, dissolving in the receiver, gives the liquor a greenish colour; but from this it may be easily freed by a second distillation, when it rises with a very gentle heat,

and

Acetous acid.

and becomes extremely white. Cryſtals of verdegris afford about one half their weight of radical vinegar; but verdegris itſelf much leſs, and of a more oily quality.

1527 Of its cryſtallization. If this acid be heated in a wide-mouthed pan, and fire applied to it, it will burn entirely away like ſpirit of wine. This obſervation we owe to the count de Lauragais, who has likewiſe obſerved, that it is capable of cryſtallization. This, however, takes place only with the laſt portions which came over, and the cryſtals appear in the form of plates or needles. The marquis de Courtrivon, who has repeated and confirmed the experiment of the count de Lauragais, ſuppoſes this phenomenon to be owing to a ſulphur-like mixture of acetous acid and phlogiſton. Leonhardi ſuppoſes an analogy between theſe cryſtals and the white ſalt of copper expelled at the end of the operation by the count de Laſſone. This ſalt was at firſt very white, and fixed on the neck of the retort pretty thick; but unleſs quickly collected, was ſoon deſtroyed by the ſucceeding vapours. When expoſed to the air, it attracts moiſture, and runs into a greeniſh liquid. It is uncommonly light, and in ſuch ſmall quantity, that ſcarce five or ſix grains can be collected from a pound of verdegris. Its taſte is acid, auſtere, very unpleaſant and permanent. It readily and totally diſſolves in water, and partially in ſpirit of wine, leaving a yellow powder totally ſoluble in volatile alkali, and which burns with a green flame. From this ſalt, volatile alkali acquires a blue colour, and litmus a red one; and thus it diſcovers itſelf to be compoſed of acetous acid and copper.

1528 Difference between radical vinegar and common acetous acid. Experience has ſhown that radical vinegar differs conſiderably in its properties from the common acid. It has a greater attraction for alkalies, forms with them more perfect combinations, and is leſs volatile. M. Berthollet obſerves, that when vinegar concentrated by froſt and radical vinegar, are reduced to equal denſities, by adding water to the heavier of the two, they differ very much both in ſmell and taſte. Laſſone found, that radical vinegar formed a cryſtallizable compound with volatile alkali; and Berthollet has obſerved the ſame with regard to fixed vegetable alkali. The cryſtals of the latter with radical vinegar were flat, tranſparent, and flexible, ſlowly deliqueſcent in the air. On comparing the ſalts formed by the two acids, he found, that the acetous ſalt rendered the ſyrup of violets green; but its colour remained unaltered with that made with radical vinegar. The latter alſo required a ſtronger fire to expel part of its acid; it was alſo whiter, and had a leſs acid taſte. On pouring radical vinegar on the acetous ſalt, the ſolution afforded, by evaporation and cryſtallization, a ſalt perfectly ſimilar to that procured directly from radical vinegar and fixed alkali. On diſtilling the mixture, the radical vinegar appeared to have expelled the common acetous acid, as the liquor which came over effervesced with vegetable alkali, and formed with it a terra foliata tartari.

"It ſeems probable (ſays Mr Keir), that the radical vinegar contains a larger portion of the aerial principle than the common acetous acid; by which it undergoes a change ſimilar to that of marine acid, when brought into that ſtate in which it is ſaid to be dephlogiſticated. This air it may acquire from the metallic calx, which being deprived of its air is reduced to its metallic ſtate. Thoſe who believe in the phlogiſton of metals, may ſay that the acid is dephlogiſticated by imparting its phlogiſton to the metal, which is thereby metallized. It appears, however, to be very diſtinct from common acetous acid, and deſerves to have its properties and compounds farther inveſtigated."

Concentrated acetous acid, of a great degree of ſtrength may alſo be obtained by diſtilling terra foliata tartari with vitriolic acid; but Leonhardi obſerves, that the acid thus obtained is always more or leſs contaminated with the volatile acid of ſulphur. He obſerves alſo, that the method propoſed of ſeparating the ſulphureous acid by a ſecond diſtillation from ſalt of tartar is not effectual, becauſe the ſulphureous acid has leſs attraction for alkalies than the acetous. Weſtendorf recommends the neutral ſalt formed by acetous acid and mineral alkali, inſtead of the terra foliata tartari. Thus, in the firſt place, we readily obtain cryſtals free from the inflammable matter of the vinegar; and, in conſequence of this, though we diſtil it afterwards with concentrated oil of vitriol, no ſulphureous taint can be produced. Even ſuppoſing this to be the caſe (he ſays), it may be removed by a ſecond diſtillation from ſome mineral alkali. Mr Keir, however, obſerves, that "probably all the acids diſtilled from acetous ſalts by means of the vitriolic, partake of the property of that procured by diſtilling cryſtals of verdegris; and none of them can compare with that from which Mr Louitz obtained acetous ether without addition, as a pure concentrated and unaltered vinegar." 1529 How to obtain it pure from terra foliata tartari.

XIV. *Acid of Benzoin.*

The properties of this acid have been inveſtigated by M. Lichtenſtein, and are as follow. 1. Expoſed to the heat of a candle in a ſilver ſpoon, it melts as clear as water, without burning, though it is deſtroyed by contact of flame. 2. When thrown upon coals, it evaporates, without reſiduum, in a thick white ſmoke. 3. It is not volatile without a conſiderable degree of heat. 4. By very ſlow cooling its aqueous ſolution yields large cryſtals, long, thin, and of a feathery ſhape. 5. It is ſoluble in the concentrated acids of nitre and vitriol, but ſeparates from them, without decompoſition, on the addition of water. 6. By the other acids it cannot be diſſolved without heat, and ſeparates from them alſo without any change, merely by cooling. 7. It is copiouſly diſſolved by ſpirit of wine, and precipitated from it on the addition of water. 8. With alkalies it forms neutral ſalts, very ſoluble in water, and of a ſharp ſaline taſte. With vegetable alkali it forms cryſtals of a pointed feathery form: with mineral alkali it yields larger cryſtals, which fall into powder on being expoſed to the air; and with volatile alkali it is difficultly cryſtallizable into ſmall, feathery, and deliqueſcent cryſtals. It is ſeparable from alkalies by the mineral acids. 9. With calcareous earth it forms white, ſhining, and pointed cryſtals, not eaſily ſoluble, and which have a ſweetiſh taſte without any pungency. 10. With magneſia ſmall 1530 M. Lichtenſtein's account of its properties.

Acetous acid.

ſmall feathery cryſtals are formed, of a ſharp ſaline taſte, and eaſily ſoluble in water. 11. An aſtringent ſalt is formed with earth of alum.

All theſe earthy ſalts are eaſily decompoſed by the mineral acids as well as by alkalies. The acid of benzoin itſelf reddens litmus, but has little effect upon ſyrup of violets.

1531 Effects of nitrous acid upon it.

Meſſrs. Hermbſtadt and Lichtenſtein have both tried the effects of nitrous acid upon that of benzoin. In this operation, however, a great obſtacle aroſe from the volatility of the acid of benzoin, which prevented it from bearing any conſiderable heat without paſſing over into the receiver. By repeated diſtillations, however, the acid of benzoin, diminiſhed in its volatility, aſſumed a darker colour, and acquired a bitteriſh taſte. A coal was alſo left at the bottom; and, at the end of the third operation, when the nitrous acid had been all drawn off, M. Hermbſtadt obſerved that ſome brown drops came over which had the appearance of a dark-coloured tranſparent oil, ſoluble in diſtilled water, emitting acrid fumes, and having a very cauſtic taſte. On diſtilling this acid liquor a ſecond time, a yellow ſaline maſs was obtained, which, when diſſolved in diſtilled water, formed a fluid acid, which precipitated a ſolution of ſugar of lead and lime-water. On examining the charred reſiduum left in the retort, he obſerved, that, after calcination, ſome of the earth had been vitrified, while another was of a ſoft conſiſtence, and had acquired a cauſtic taſte. From a mixture of the abovementioned dark-brown acid and ſpirit of wine, he obtained an ether, which differed from the nitrous in being much leſs volatile, and ſmelling like bitter almonds.

From this reſiduum Mr Lichtenſtein obtained a reſinous ſubſtance, to which he aſcribes the volatility of the acid of benzoin, as well as the ſmell of bitter almonds already mentioned.

Scheele failed in his attempt to obtain ether from flowers of benzoin and ſpirit of wine; but, by adding a little ſpirit of ſalt, he obtained a kind of ether which fell to the bottom. On diſſolving this in alkalized ſpirit of wine, and drawing off the latter by diſtillation, he obtained from it a quantity of flowers of benzoin. From Peruvian balſam alſo Lehman obtained a quantity of the acid of benzoin. It may alſo be procured from urine, either by precipitation, from the ſaponaceous extract (A), or by repeatedly diſtilling from it ſpirit of nitre, as in the preparation of acid of ſugar. In the urine it is found combined with volatile alkali, by which it becomes ſoluble in ſpirit of wine.

1532 Acid of benzoin procurable from Peruvian balſam and urine.

XV. *Sebaceous Acid.*

Sebaceous acid.

This is ſaid to have been firſt diſcovered by Mr Gruitzmacker, who publiſhed an account of it in 1748. It was afterwards more accurately treated of by Mr Rhades in 1753. Its properties were inveſtigated by Meſſrs Segner and Knappe in 1754; and afterwards more fully by Dr Crell, of whoſe diſcoveries an account is given in the Philoſophical Tranſactions for 1780 and 1782. It is found not only in the fat of all animals, but in ſpermaceti, the butter of cocoa, and probably in other vegetable oils. In ſeveral reſpects it ſeems analogous to the marine acid; but in others it is remarkably different, particularly in precipitating a ſolution of corroſive ſublimate. It is probable, however, that is principles are the ſame with thoſe contained in all other vegetable and animal acids; and this opinion is ſupported by what happens on treating tallow in the uſual manner for obtaining acid of ſugar; for thus, not the ſebaceous, but the ſaccharine acid is found to be produced. It has a very great ſtrength of attraction, and by means of heat decompounds even the vitriolic ſalts themſelves; but in the moiſt way is expelled by the three mineral acids, though it expels all the vegetable ones as well as thoſe of fluor and arſenic. Its moſt remarkable property is its effect on tin. The filings of this metal, eſpecially with the aſſiſtance of heat, are corroded by it into a yellow powder, and at the ſame time give out a very fetid ſmell. The ſolution, though filtered, ſtill continues turbid, and depoſits more yellow powder, acquiring at the ſame time a fine roſe-red colour. By adding water to this yellow powder, a white deliqueſcent ſalt may be obtained, and a ſimilar one obtained by diſſolving a yellow powder precipitated by this acid from ſolution of tin in aqua-regia.

1533 Sebaceous acid procurable from various ſubſtances.

1534 Has a remarkable power of attraction.

1535 Remarkable effect on tin.

1536 Its effects on other ſubſtances.

It corrodes lead rather than diſſolves it; but diſſolves a conſiderable quantity of minium, and changes the reſt to a white powder. This ſolution is ſweetiſh, and is not precipitated by common ſalt. The metal is precipitated by ſebaceous acid from the nitrous, in white needle-like cryſtals, eaſily ſoluble in water. A like precipitation takes place in ſolution of ſugar of lead; but the precipitate is ſtill ſoluble in ſtrong vinegar, provided it be not adulterated with oil of vitriol. In its elective attractions it agrees with the acids of apples and of fluor, preferring magneſia to fixed alkali.

XVI. *Acid of Galls.*

Though it has for a long time been known that the infuſion of galls has the property of reddening vegetable juices, diſſolving iron, and decompoſing liver of ſulphur, theſe effects were generally aſcribed to its aſtringency. Of late, however, it has been found, that beſides this aſtringent principle a true acid exiſts in galls; and to this, rather than to the aſtringent principle, are we to aſcribe the properties of galls in ſtriking a black with ſolution of vitriol, &c.

1537 Method of ſeparating the acid.

To ſeparate the acid from the other matters contained in the galls, we muſt add fixed alkali to a decoction of them; by which means the aſtringent matter will be thrown down, and the acid remain in the liquor joined to the alkali, the precipitate, waſhed with clean water, dried, and rediſſolved, blackened a ſolution of vitriol but faintly, and no more than what may be ſuppoſed to proceed from ſome remaining acid, which could not be abſtracted. This is proved by diſtilling

(A) By this is meant urine evaporated to a thick conſiſtence, and deprived of moſt of its ſalts by ſolution in ſpirit of wine.

Acid of galls.

ſtilling the aſtringent matter in queſtion, when an acid liquor comes over, which has the property of blackening ſolution of vitriol. Scheele has obſerved, that

1538 An acid obtained from galls by diſtillation. when galls in ſubſtance are expoſed to diſtillation, an acid liquor riſes of an agreeable ſmell, without oil, and afterwards a kind of volatile ſalt, which is the true acid of the galls. Hence he infers, that this ſalt is contained ready formed in the galls themſelves; but ſo much involved in ſome gummy or other matter, that it cannot be eaſily obtained ſeparately.

The acid of galls is capable of being ſeparated by cryſtallization. In an infuſion made with cold water, Scheele obſerved a ſediment which appeared to have a cryſtalline form, and which was acid to the taſte, and had the property of blackening ſolution of vitriol. By expoſing the infuſion for a long time to the air, and removing from time to time the mouldy ſkin which grew upon it, a large quantity of ſediment was formed. On rediſſolving this in warm water, filtering and evaporating it very ſlowly, an acid ſalt was obtained

1539 Properties of this acid. in ſmall cryſtals like ſand, which had the following properties: 1. It taſted acid, effervesced with chalk, and reddened litmus. 2. Three parts of boiling water diſſolved two of the ſalt; but 24 parts of cold water were required to diſſolve one. 3. It is likewiſe ſoluble in ſpirit of wine; four parts of which are required to diſſolve one of the ſalt when cold, but only an equal quantity when aſſiſted by a boiling heat. 4. The ſalt is deſtructible by an open fire, melts and burns with a pleaſant ſmell, leaving behind a hard inſoluble coal, which does not eaſily burn to aſhes. 5. By diſtillation an acid water is firſt obtained without any oil: then a ſublimate, which remains fluid while the neck of the retort is hot, and then cryſtallizes. This ſublimate has the taſte and ſmell of flowers of benzoin; is ſoluble in water and in ſpirit of wine; reddens litmus; and precipitates metallic ſolutions of the following colours, viz. gold of a dark brown; ſilver of a grey colour; copper of a brown; iron of a black; lead of a white colour; mercury of an orange; biſmuth, lemon-coloured. The acid of molybdæna became yellow coloured, but no precipitate enſued. Solutions of various kinds of earths were not altered; but lime-water afforded a copious grey-coloured precipitate. 6. By treating this acid with that of nitre, in the manner directed for producing acid of ſugar, it was changed into the latter.

XVII. *Identity of the Vegetable Acids.*

On the proofs of the identity of the vegetable acids

1540 Mr Keir's objections to the opinions on this ſubject. with one another, Mr Keir makes the following remarks: "The experiments and obſervations which have been made, prove evidently a ſtrong analogy between the acetous acid, ſpirit of wine, tartar, and acid of ſugar; and they ſeem to ſhow the exiſtence of a common principle or baſis in all of them, modified either by the addition of another principle not common to all of them, or by different proportions of the ſame principle. None of the opinions on this ſubject, however, are quite ſatisfactory. The production of the acetous acid by treating ſpirit of wine with other acids, does not prove that the acetous acid was contained in the ſpirit of wine, but only in concurrence with them, that they contain ſome common principle. There is no fact adduced to ſupport Morveau's Indentity of the vegetable acids. opinion, that fixed air is abſorbed during the acetous fermentation; or that the preſence of this fixed air is neceſſary. The decompoſition of all vegetable acids by heat, and the production therefrom of fixed and inflammable gaſes, ſhow that theſe acids contain ſome of the ſame principles as theſe elaſtic fluids, but do not prove that the gaſes exiſted in the fluids. We have good reaſon to believe that acetous acid does not contain any fixed air already formed; for it yields none when vitriolic acid is added to it, or to foliated earth; nevertheleſs, my opinion that vegetable and animal acids are, by heat, in a great meaſure convertible into fixed air, ſeems to be ſufficiently proved by experiments. Thus Hales has ſhown the great quantities of 1542

Quantities of the different ſubſtance obtained from foliated earth. this gas which tartar yields on diſtillation. Berthollet has obtained the fixed and inflammable gaſes from foliated earth; and Dr Higgins has verified this experiment, and deduced the quantities. From 7680 grains of foliated earth, the Doctor obtained.

Cauſtic alkali	-	3862.994 grains.
Fixed air	-	1473.564
Inflammable air	-	1047.6018
Oily matter retained in the reſiduum	- -	78
Oil	- - -	182
Water condenſed	-	340
Deficiency attributed chiefly to water	- -	726.9402"

As fixed and inflammable gaſes may be obtained from every vegetable ſubſtance by fire, nothing can be inferred from theſe experiments to explain particularly the nature of the acetous acid, excepting that it contains ſome of the inflammable matter common to the vegetable kingdom, and eſpecially of the matter common to vegetable acids; all which alſo, when analyſed, furniſh large quantities of theſe two gaſes.

"Although we are far (adds our author) from the knowledge requiſite to give a complete theory of the acetous fermentation, yet it may be uſeful to explain the ideas that appear moſt probable. In all the inſtances that we know of the formation of acids, whether effected by combuſtion, as the acids of ſulphur and phoſphorus, or by repeated abſtractions of nitrous acid, as in the proceſs for making acid of ſugar, a very ſen- 1543

Air abſorbed in the formation of all acids. ſible quantity of pure air is abſorbed. In the caſe of combuſtion we know, from the weight acquired, that there is a great abſorption of air; and in the latter caſe, of acids being produced by application of nitrous acid, as this acid conſiſts of nitrous and pure air, and as in theſe operations a quantity of the nitrous gas is expelled, there ſeems but little doubt that there alſo the pure air of the nitrous acid is united with the ſubſtance employed in the formation of the new acid. Hence, from all that we know, the abſorption of air takes place in all acidifying proceſſes. But it alſo actually takes place in the acetous fermentation, as has been obſerved, particularly by the Abbe Rozier; and it is generally known, that air is neceſſary to the formation of vinegar. The next queſtion is, What is the baſis? And from the experiments already related, of forming the acetous acid by means of ſpirit of wine, it ſeems probable, either that this ſpirit is the baſis of the acetous acid, or that it contains this baſis: and from the convertibility of the acids of tartar and of

ſugar

Identity of the vegetable acids. fugar into the acetous acid by the proceffes above defcribed, it feems probable that thefe alfo contain the fame common bafis; which, being united with a determined quantity of pure air, forms acid of tartar; with a larger quantity, acid of fugar; and with a ftill larger, the acetous acid.

1544 Inflammable fpirit produced from radical vinegar. "An inflammable fpirit is faid to appear at the end of the diftillation of radical vinegar from verdigris. Now, if the ardent fpirit were contained in the verdigris, as it is more volatile than the acid, it ought to come over firft; but as it appears only towards the end of the diftillation, it feems to be formed during the operation; and I imagine, that the metal, when almoft deprived of its acid, attracts fome of the air of the remaining acid; and the part or bafis of the acid thus deprived of its air becomes then an inflammable fpirit, and in fome cafes an oil appears. But as the quantity of acid thus decompofed is very fmall, and little air of confequence remains united with the metallic part of the verdigris, the copper appears rather in a metallic than calciform ftate after the operation. But zinc, during its folution in concentrated vinegar, decompofes the acid as it does the vitriolic and other

1545 Sulphureous inflammable vapours produced from it. ftrong acids, and accordingly inflammable vapours are produced; and what is remarkable, thefe vapours have a fulphureous fmell. Iron always, during its folution in concentrated vinegar, produces an expulfion of inflammable vapours; which, however, do not explode like inflammable gas.

1546 Of the conftituent parts of the acetous acid. "We muft not imagine that we are yet able to explain completely what paffes in the acetous fermentation, or that the acetous acid is a compound of mere fpirit and pure air. Befides this combination of fpirit and air, it is obferved, that a precipitation always takes place before the fermentation is completed, of fome mucilaginous matter, which difpofes the vinegar to putrefy, and from which it therefore ought to be carefully feparated. Stahl affirms, that without a depofition of fuch fediment, vinegar cannot be made from fugar, wine, or other juice. Befides the matter that is depofited, probably as much remains in the liquor as can be diffolved therein; for, by diftillation, much of a fimilar extractive matter is left in the retort. What the nature of this matter is, and how it is formed, has not yet been examined. Though diftillation frees the acid from much of this extractive fubftance, yet we have no reafon to believe that we have ever obtained it entirely free from inflammable matter; as it retains it even when combined with alkalies and with metals. When fugar of lead and other acetous falts are diftilled with a ftrong heat, the fubftances remaining in the retort have been obferved to poffefs the properties of a pyrophorus; and this will happen whatever pains have been taken to purify the vinegar employed. See the article Pyrophorus. This fact fhows the exiftence of an inflammable matter in this acid; and which may perhaps be effential in its com-

1547 It is formed in various chemical proceffes. pofition, and neceffary to its properties. Although fermentation is the ufual mode of obtaining acetous acid, yet it appears from the inftances obferved by latter chemifts, that it is not effential to its formation, but that it is alfo formed in various chemical proceffes; and the acid obtained by diftillation from woods, wax, &c. are very analogous to vinegar. It appears alfo on treating the acid of fugar with nitrous acid, as has been obferved both by Weftrumb and Scheele. The latter further acquaints us, that he obtained it in analyfing a tallow like oil, which remained undiffolved upon digefting ftarch in nitrous acid. As acid of fugar alfo may be obtained from a variety of animal fubftances, and as this acid is convertible into the acetous we have one reafon more added to many others, to prove that the matters of vegetable and animal fubftances are not capable of any chemical diftinction." Addition to Sect. I. § 20.

XVIII. Addition to Sect. I. § 20. *concerning the volatility of a Mixture of Marine and Nitrous Acids.*

1548 How to deprive aqua-regia of its volatility. This is much lefs fenfible when the acids are weak than when they are concentrated. On mixing the two when moderately fmoking, and which had remained for a long time feparate without occafioning any difturbance, a vaftly fmoking aqua-regia has been produced, which would either drive out the ftopple, or burft the bottle in warm weather. On diftilling a pretty ftrong nitrous acid from fal ammoniac, M. Beaumé obferved, that the vapours which came over were fo exceedingly elaftic, that notwithftanding every precaution which could be taken in fuch a cafe, the diftillation could not be continued. By letting this efcape, however, Mr Cornette obferved, that the diftillation of thefe two fubftances may be carried on to the end without any inconvenience, and the aqua-regia will then be no longer troublefome.

XIX. *Test for Acids and Alkalies.*

The general method recommended for difcovering a fmall quantity of acid or alkali in any liquid, is by trying it with any vegetable blue, fuch as fyrup of violets; when, if the acid prevails in the liquor, the fyrup will acquire a red colour, more or lefs deep according to the quantity of acid; or if the alkali prevail, it will change the fyrup green in like proportion. 1549

Inaccuracy of the common tefts. Since the late improvements in chemiftry, however, the fyrup has been found deficient in accuracy, and the infufion of turnefole, or of an artificial preparation called litmus, have been fubftituted inftead of it. The infufion of litmus is blue, and, like fyrup of violets, becomes red with acids. It is fo fenfible that it will difcover one grain of oil of vitriol though mixed with 100,000 of water. Unfortunately, however, this infufion does not change its colour on mixture with alkalies; it is therefore neceffary to mix it with juft as much vinegar as will turn the infufion red, which will then be reftored to its blue colour by being mixed with any alkaline liquor. The blue infufion of litmus is alfo a teft of the prefence of fixed air in water, with which it turns red, as it does with other acids.

The great fenfibility of this teft would leave very little reafon to fearch for any other, were it always an exact teft of the point of faturation of acids and alkalies; but, from the following fact, this appears to Mr Watt to be dubious. A mixture of phlogifticated nitrous acid with an alkali will appear to be acid by the teft of litmus, when other tefts, fuch as the infufion of the petals of the fcarlet rofe, of the blue iris, of violets, and of other flowers, will fhow the fame liquor to be alkaline, by turning green fo evidently as to leave no room to doubt.

When Mr Watt made this difcovery, the fcarlet rofes, Teſt for acids and alkalies.

ſes, and ſeveral other flowers, whoſe petals change their colour by acids and alkalies, were in flower. Having ſtained paper with their juices, he found that it was not affected by the phlogiſticated nitrous acid, excepting in ſo far as it acted the part of a neutralizing acid; but he found alſo, that, paper ſtained in this manner was much leſs eaſily effected than litmus was; and that, in a ſhort time, it loſt much of the ſenſibility which it poſſeſſed at firſt; and having occaſion in winter to repeat ſome experiments in which the phlogiſticated nitrous acid was concerned, he found his

1550 Red cabbage anſwers the purpoſe beſt.

ſtained paper almoſt uſeleſs. Searching, therefore, for ſome other vegetables which might ſerve for a teſt at all ſeaſons of the year, he found the red cabbage to anſwer his purpoſe better than any other; having both more ſenſibility with regard to acids than litmus, being naturally blue, and turning green with alkalies, and red with acids; to all which is joined the advantage of its being no farther affected by the phlogiſticated acid of nitre than as it acts as a real acid.

1551 How to prepare it for uſe.

To prepare this teſt, Mr Watt recommends to take the freſheſt leaves of the cabbage; to cut out the large ſtems, and mince the thin parts of the leaves very ſmall; then to digeſt them in water at about the heat of 120 degrees for a few hours, when they will yield blue liquor; which, if uſed immediately as a teſt, will be found to poſſeſs great ſenſibility: but as in this ſtate it is very apt to turn putrid, ſome of the following methods muſt be uſed for preſerving it.

1. After having minced the leaves, ſpread them on paper, and dry them in a gentle heat; when perfectly dry, put them up in glaſs bottles well corked; and, when you want to uſe them, acidulate ſome water with vitriolic acid, and digeſt or infuſe the dry leaves in it, until they give out their colour; then ſtrain the liquor through a cloth, and add to it a quantity of fine whiting or chalk, ſtirring it frequently, until it becomes of a true blue colour, neither inclining to green nor purple; when you perceive that it has acquired this colour, filter it immediately; otherwiſe it will become greeniſh by ſtanding longer on the whiting. This liquor will depoſit a ſmall quantity of gypſum, and, by the addition of a little ſpirit of wine, will keep good for ſome days; but will then become ſomewhat putrid and reddiſh. If too much ſpirit is added, it deſtroys the colour. If the liquor is wanted to keep longer, it may be neutralized by a fixed alkali inſtead of chalk.

2. As thus the liquor cannot be long preſerved without requiring to be neutralized afreſh juſt before it is uſed; and as the putrid fermentation which it undergoes, and perhaps the alkalies or ſpirit of wine mixed with it, ſeem to leſſen its ſenſibility; in order to preſerve its virtues while kept in a liquid ſtate, ſome freſh leaves of the cabbage, minced as above directed, may be infuſed in a mixture of vitriolic acid and water, of about the degree of acidity of vinegar; and it may be neutralized, as it is wanted, either by means of chalk, or of the fixed or volatile alkali. It muſt be obſerved, however, that if the liquor has an exceſs of alkali, it will ſoon loſe its colour, and become yellow; from which ſtate it cannot be reſtored; care ſhould therefore be taken to bring it very exactly to a blue, and not to let it verge towards a green.

3. In this manner, Mr Watt prepared a red infuſion of violets; which, on being neutralized, formed a very ſenſible teſt, though he did not know how long theſe properties would be preſerved; but he is of opinion that the coloured infuſions of other vegetables may be preſerved in the ſame manner by the antiſeptic power of the vitriolic acid, in ſuch a manner as to loſe little of their original ſenſibility. Paper freſh ſtained with theſe teſts, in their neutral ſtate, has ſufficient ſenſibility for many experiments; but the alum and glue which enter into the preparation of writing paper, ſeem, in ſome degree, to fix the colour; and paper which is not ſized becomes ſomewhat tranſparent when wetted; which renders ſmall changes of colour imperceptible. Where accuracy is required, therefore, the teſt ſhould be uſed in a liquid taſte.

1552 Various other teſts.

4. Our author has found that the infuſion of red cabbage, as well as of various flowers in water, acidulated by means of vitriolic acid, are apt to turn mouldy in the ſummer ſeaſon, and likewiſe that the moulding is prevented by an addition of ſpirit of wine. He has not been able to aſcertain the quantity of ſpirit neceſſary for this purpoſe, but adds it by little and little at a time until the proceſs of moulding is ſtopped.—Very ſenſible teſts are afforded by the petals of the ſcarlet roſe, and of the pink coloured lychnis treated in the abovementioned manner.

XX. *Volatile Alkali.*

Volatile alkali.

1553 Volatile alkali prepared from nitrous acid and tin.

Mr Higgins claims the firſt diſcovery of the conſtituent parts of volatile alkali, or at leaſt of an experiment leading to it. "About the latter end of March 1785 (ſays he), I found that nitrous acid poured on tin filings, and immediately mixed with fixed vegetable alkali, generated volatile alkali in great abundance: ſo ſingular a fact did not fail of deeply impreſſing my mind, though at the time I could not account for it. About a fortnight after, I mentioned the circumſtance to Dr Brockleſby. He told me he was going to meet ſome philoſophical gentlemen at Sir Joſeph Banks's, and deſired I would generate ſome alkali to exhibit before them: accordingly I did; and had the pleaſure of accompanying him thither. The December following I mentioned the fact to Dr Caulet, and likewiſe the copious generation of volatile alkali from Pruſſian blue, vegetable alkali, and water; on which we agreed to make a ſet of experiments upon the ſubject. At preſent I ſhall only give an account of the following, which drew our particular attention. Into a glaſs cylinder, made for the purpoſe, we charged three parts of alkaline air, and to this added one part of dephlogiſticated air;

1555 Effects of the electric ſpark on it.

we paſſed the electrical ſpark repeatedly in it, without apparently effecting the ſmalleſt change. When it had received about 100 ſtrong ſhocks, a ſmall quantity of moiſture appeared on the ſides of the glaſs, and the braſs conductors ſeemed to be corroded; when we had paſſed 60 more ſhocks in it, the quantity of moiſture ſeemed to increaſe, and acquire a greeniſh colour, though at this time the column of air ſuffered no diminution. On examining the air, it burned with a languid greeniſh flame, from which we inferred that the dephlogiſticated air was totally condenſed: it ſtill retained an alkaline ſmell; and the alkaline part was not readily abſorbed by water.

"From

Pruſſian blue.

" From Mr Cavendiſh's famous diſcovery of the conſtituent parts of water we could readily account for the loſs of the dephlogiſticated air in this experiment; but the quantity of water was more than we could expect from this: therefore water muſt have been precipitated from the decompoſed alkali; for volatile alkali, from its great attraction to water, muſt keep ſome in ſolution even in its aeriform ſtate. From the above circumſtances it might be expected,
1556 that a contraction of the column of air ſhould take place; but it muſt be conſidered, that the union took place gradually in proportion as the alkali was decompoſed; and that, in this caſe, the expanſion muſt equal the condenſation.

True compoſition of volatile alkali.

During the ſpring of 1786 I had often an opportunity of mentioning different facts to Dr Auſtin relating to volatile alkali, who at that time was too much engaged to pay attention to the ſubject. In the end of Auguſt 1787, he gave me an account of a ſet of experiments which he had made, and which actually proved, that volatile alkali conſiſts of light inflammable and phlogiſticated airs; not knowing at that time what Meſſrs Houſman and Berthollet had done. Without depreciating the merit of theſe two gentlemen, Dr Auſtin has an equal claim to the diſcovery, laying aſide priority; as his experiments are as deciſive as theirs. Dr Prieſtley made the firſt ſtep towards our knowledge of volatile alkali."

XXI. *Prussian Blue.*

1557 The acid of this ſubſtance, as far as it contains an acid, is ſuppoſed to be that of phoſphorus. Mr Woulfe propoſed a teſt of this kind for diſcovering iron in mineral waters, which, he obſerved, would not be affected by acids; but the lixivium deſcribed by him had the bad property of letting fall the Pruſſian blue it contains in a few weeks. The precipitate of copper, however, treated again with alkali, retained this property upwards of nine months. The volatile alkali, he obſerves, is diſſolved by the Pruſſian acid; and the cryſtals depoſited are rendered blue by the colouring

Woulfe's teſt for mineral waters.

1558 matter, though the colour at firſt is loſt by the union of the alkali with the ſubſtance already made. The metals were precipitated by this teſt of the following colours: Gold of a browniſh yellow, the precipitate afterwards becoming of a full yellow; platina of a deep blue, but when quite pure, of a yellow colour, turning ſlightly green. Silver in the nitrous acid was precipitated of a whitiſh colour; copper from all the different acids was precipitated of a deep brown colour, the liquid remaining greeniſh; green vitriol let fall a deep blue powder, leaving a colourleſs lixivium; ſugar of lead and muriated tin gave a white powder; nitrated mercury a white or yellowiſh precipitate; the Illfeld mangane ſe a browniſh, but that from Devonſhire a blue, which firſt became aſh-coloured and then reddiſh. Nitrated biſmuth afforded a white precipitate, and the lixivium was ſlightly green: muriated antimony yielded a white precipitate, with a yellowiſh lixivium: vitriolated zinc a whitiſh: cobalt in aqua-regia a reddiſh white powder: the precipitate of arſenic and the different earths was commonly white.

Effect of it on various metallic ſolutions.

XXIII. *New Chemical Nomenclatures.*

New chemical nomenclatures.

1. *Of that propoſed in 1787 by Meſſrs Morveau, Berthollet, Fourcroy, and Lavoiſier.*

When this nomenclature was firſt publiſhed, M. Lavoiſier informs us, that ſome blame was thrown upon the authors for changing the language, which had received the ſanction of their maſters, and been adopted by them. In anſwer to this, however, he urges, that Meſſrs Bergman and Macquer had expreſſed a wiſh for ſome reformation in the chemical language. Mr Bergman had even written to M. Morveau on the ſubject in the following terms. " Show no favour to any improper denomination: Thoſe who are already poſſeſſed of knowledge, cannot be deprived of it by new terms; thoſe who have their knowledge to acquire, will be enabled by your improvement on the language of the ſcience to acquire it ſooner." 1559

Bergman's letter to Morveau on this ſubject.

The following is M. Lavoiſiers explanation of the principles on which his new language is compoſed. " Acids conſiſt of two ſubſtances, belonging to that order which comprehends ſuch as appear to us to be ſimple ſubſtances. The one of theſe is the principle of acidity, and common to all acids; from it therefore ſhould the name of the claſs and genus be borrowed: The other, which is peculiar to each acid, and diſtinguiſhes them from one another, ſhould ſupply the ſpecific name. But in moſt of the acids, the two conſtituent principles, the acidifying and the acidifyed, may exiſt in different proportion, forming different degrees of equilibrium or ſaturation; this is obſerved of the *ſulphuric* and *ſulphureous* acid. Theſe two ſtates of the ſame acid we have expreſſed by varying the termination of the ſpecific name. 1560

Lavoiſier's explanation of the new nomenclature.

" Metallic ſubſtances, after being expoſed to the compound action of air and fire, loſe their metallic luſtre, gain an increaſe of weight, and aſſume an earthy appearance. In this ſtate they are, like acids, compound bodies, conſiſting of one principle common to them all, and another peculiar to each of them. We have therefore in like manner claſſed them under a generic name, derived from the principle which is common to them all. The name which we have adopted is *Oxide*: The peculiar names of the metals from which they are formed, ſerve to diſtinguiſh theſe compounds from one another.

" Combſtuible ſubſtances, which, in acids and metallic oxides, exiſt as ſpecific and peculiar principles, are capable of becoming, in their turn, the common principle of a great number of ſubſtances. Combinations of ſulphur, were long the only compounds of this ſort known: but of late the experiments of Meſſrs Vandermonde, Monge, and Berthollet, have ſhown that coal combines with iron and perhaps with various other metals; and that the reſult of its combination with iron are, according to the proportions, ſteel, plumbago, *&c.* It is alſo known from the experiments of M. Pelletier, that phoſphorus combines with many metallic ſubſtances. We have therefore arranged theſe different combinations together under generic names, formed from the name of the common ſubſtance, with a termination indicating this analogy; and have diſtinguiſhed them from each other by ſpecific names derived from the names of the peculiar ſubſtances.

" It

New chemical nomenclatures.

"It was found somewhat more difficult to form a nomenclature for the compounds of those three simple substances; because they are so very numerous, and still more, because it is impossible to express the nature of their constituent principles, without using more compound names. In bodies belonging to this class, such as neutral salts for instance, we had to consider, 1. the acidifying principle common to them all; 2. the acidifiable principle which peculiarizes the acid; 3. the saline, earthy, or metallic base, which determines the particular species of the salt. We have derived the name of each class of salts from that of the acidifiable principle, common to all the individuals of the class; and have then distinguished each species by the name of the *saline*, *earthy*, or *metallic* base peculiar to it.

"As salt, consisting of any three principles, may, without losing any of these principles, pass through different states by the variation of their proportions; our nomenclature would have been defective without expressions for these different states. We have expressed them chiefly by a change of termination, making all names of salts in the same state to end with the same termination."

2. *Nomenclature by M. Wiegleb.*

1561 Mr Wiegleb's nomenclature.

In Wiegleb's General System of Chemistry translated by Hopson, we have another nomenclature formed on different principles. In this he gives to fixed vegetable alkali the name of *Spodium*, from the Greek word σποδος *(ashes)*. The mineral alkali he calls *natrum*, the name by which it was anciently distinguished; and the volatile alkali *ammonium*, from sal ammoniac which contains it in great quantity. The compound salts may be distinguished into double, triple, and quadruple; though, in the scheme given in the work, the first division is omitted, as tending only to create confusion. The irregular salts, consisting of those which are triple and quadruple, are admitted. Such as are imperfect by reason of an excess of acid, he says, are best denominated by converting the adjective, expressive of the base, into a participle; a practice which, on many occasions, though countenanced by the authority of a late eminent writer, seems aukward and stiff. The excess of acid is denominated by the word *hyperoxys*, and a defect of it by *hypoxys*. Hence his denominations are formed in the following manner.

Salts with excess of acid. Cream of tartar, or *tartarus spodatus*, or *tartaroxys spodicus*. Acid vitriolated tartar, or vitriolum spodatum, *vitrioloxys spodicus*.

The salts which are imperfect from a defect of acid have their denominations by mentioning the base before the acid, and expressing the former substantively, the latter adjectively. Thus,

Salt of tartar, aerated vegetable alkali, spodium aerocraticum,	Oxyspodium, aerocraticum.
Aerated volatile alkali, ammoniacum aerocraticum,	Oxyammonium aerocraticum.
Chalk, or calx aerocratica,	Oxycalcitis aerocraticus.
Borax, or natrum boracicum.	Oxynatrum boracicum.

With respect to other terms, Mr Wiegleb expresses the acid with which any base is combined, by the termination *cratia*, from the Greek κρατος *(robur)*, added to it; excepting only those with the nitrous and muriatic acids: and these (for what reason does not appear) he calls *Aponitra* and *Epimuriæ*. His genera of salts are as follow.

1. Vitriols *(Sulphurocratia)*. 2. Nitres *(Aponitra)*. 3. Murias *(Epimuriæ)*. 4. Boraxes. 5. Fluoricrates. 6. Arsenicrates. 7. Barylithicrates, (those with acid of tungsten). 8. Molybdænocrates. 9. Photocrates, (with acid of phosphorus). 10. Electrocrates. 11. Oxycrates, (with the acetous acid); or *epoxycrates*, with the aerated acid). 12. Tartars; or, with the acid changed by fire, *pyro-tartars*. 13. Oxalidicrates. 14. Cecidocrates (with the acid of galls). 15. Citriocrates. 16. Melicrates (with the acid of apples). 17. Benzicrates. 18. Xylocrates. 19. Gummicrates. 20. Camphoricrates. 21. Aerocrates. 22. Galacticrates. 23. Gala-melicrates (with acid of sugar of milk). 24. Myrmecicrates. 25. Cyanocrates (with the colouring matter of Prussian blue). 26. Steatocrates. 27. Bombycicrates. 28. Zoolithocrates, (with acid of calculus).

On the subject of nomenclatures it is obvious to remark, that whatever may be the defects of the old one, we are ready to be involved in much greater difficulties by the introduction of a new one. Or supposing a new language to be adopted, where would be the security for its permanence? That which appears most specious at one period, may still be superseded by the refinements of another; and colourable pretensions would never be wanting to successive innovators. Hence a continual fluctuation, and an endless vocabulary. As the nomenclature first abovementioned, however, has attracted no small degree of attention, we shall here subjoin a scheme of it, as well for the satisfaction of our readers in general, as for the gratification of those in particular who may have imbibed the doctrines of its authors.

[Follows *The Whole-sheet Table*.]

IBITING THE CHEMICAL NOMENCLATURE,

E MORVEAU, LAVOISIER, BERTHOLLET, and DE FOURCROY, in May 1787.

EDUCED BY THE C.	III. THE SAME SUBSTANCES COMBINED WITH OXIGENE.		IV. THE SAME SUBSTANCES IN AN OXIGENATED GAZEOUS STATE.		V. THESE OXIGENATED SUBSTANCES NEUTRALIZED BY EHE ADDITION OF BASES.		VI. THE SAME PRIMARY SUBSTANCES COMBINED WITH OTHER SUBSTANCES BUT NOT AICIDIFIED.		
NAMES.	NAMES NEWLY INVENTED OR ADOPTED.	ANCIENT NAMES.	NAMES NEWLY INVENTED OR ADOPTED.	ANCIENT NAMES.	NAMES NEWLY INVENTED OR ADOPTED.	ANCIENT NAMES.	NAMES NEWLY INVENTED OR ADOPTED.	ANCIENT NAMES.	
—	—	—	—	—	—	—	—	—	1
—	—	—	—	—	—	—	—	—	2
licated or *vital*	—	—	—	—	—	—	—	—	3
ble gas.	Water.	*Water.*	—	—	—	—	—	—	4
ated air, or *at- ric mephitis.*	The baſe of nitrous gas. Nitric acid. *With an exceſs of azote.* Nitrous acid.	*The baſe of nitrous gas.* *White nitrous acid.* *Fuming nitrous acid.*	Nitrous gas. Nitrous acid gas.	—	Nitrate of potaſh. of ſoda, &c. Nitrite of potaſh.	*Common nitre.* *Cubic nitre.*	—	—	5
—	Carbonic acid.	*Fixed air*, or *cretaceous acid.*	Carbonic acid gas.	*Fixed air, mephitic air.*	Carbonate of lime. of potaſh, &c of iron, &c.	*Chalk.* *Effervescent alkalies.* *Ruſt of iron, &c.*	Carbure of iron.	*Plumbago.*	6
—	Sulphuric acid. *With leſs oxigene,* Sulphureous acid.	*Vitriolic acid.* *Sulphureous acid.*	 Sulphureous acid gas.	 *Sulphureous acid gas.*	Sulphate of potaſh. of ſoda. of lime. of aluminous earth. of barytes. of iron, &c. Sulphite of potaſh, &c.	*Vitriolated tartar.* *Glauber ſalt.* *Selenite.* *Alum.* *Ponderous ſpar.* *Vitriol of iron, &c.* *Stahl's ſulphureous ſalt.*	Sulphure of iron. of antimo. of lead. Sulph. hydrogen. gas. Sulphure of potaſh. Sulphure of ſoda. Alkaline ſulphures with metals ſuſpended in them. Alkaline ſulphure with carbonaceous matters ſuſpended in it.	*Factitious iron pyrites.* *Antimony.* *Galena.* *Hepatic gas.* *Alkaline livers of ſulphur.* *Metallic livers of ſulphur.* *Liver of ſulphur with carbonaceous matters ſuſpended in it.*	7
—	Phoſphoric acid. *With a ſmaller proportion of oxigene,* Phoſphorous acid.	*Phoſphoric acid.* *Fuming or volatile phoſphoric acid.*	—	—	Phoſphate of ſoda. Calcareous phoſphate. Superſaturated phoſphate of ſoda. Phoſphite of potaſh, &c	*Phoſphoric ſalt with a baſe of natrum.* *Earth of bones.* *Haupt's ſal perlatum.*	Phoſphoriſed hydrogenous gas. Phoſphure of iron.	*Phoſphoric gas.* *Syderite.*	8
—	Muriatic acid *With an exceſs of oxigene,* Oxigenated muriatic acid.	*Marine acid.* *Dephlogiſticated marine acid.*	Muriatic acid gas. Oxigenated muriatic acid gas.	*Marine acid gas.* *Dephlogiſticated marine acid gas.*	Muriate of potaſh Muriate of ſoda. Calcareous muriate, &c Ammoniacal muriate. Oxigenated muriate of ſoda, &c.	*Febrifuge ſalt of Sylvius.* *Marine ſalt.* *Calcareous marine ſalt.* *Sal ammoniac.*	—	—	9
—	Boracic acid.	*Sedative ſalt.*	—	—	Borate ſuperſaturated with ſoda, *or borax* Borate of ſoda, &c. *ſoda ſaturated with the acid.*	*Common borax.*	—	—	10
—	[illegible]ic acid.	*Acid of ſpar.*	Fluoric acid gas.	*Spathoſe gas.*	Fluate of lime, &c.	*Fluor ſpar.*	—	—	11
—	Succinic acid.	*Volatile ſalt of amber.*	—	—	Succinate of ſoda, &c.	—	—	—	12
—	Acetous acid	*Diſtilled vinegar.*	—	—	of potaſh. of ſoda. of lime	*Terra foliata tartari.* *Mineral terra foliata.* *Calcareous acetous ſalt*	—	—	13

in						Oxide of nickel.	*Calx of nickel.*						
	Regulus of cobalt.	—	—	—	—	Grey / Vitreous } oxide of cobalt.	*Calx of cobalt.*	Alkaline cobaltic oxides.	*Precipitates of cobalt again diſſolved by alkalies.*	—	—	—	—
	— —	—	—	—	—	White / Yellow / Vitreous } oxide of biſmuth.	*Magiſtery of biſmuth,* or *white paint.* *Yellow calx of biſmuth.* *Glaſs of biſmuth.*	Sulphurated oxide of biſmuth.	*Biſmuth precipitated by liver of ſulphur.*	—	—	—	
	Regulus of antimony.	—	—	—	—	Oxide of antimony { by the nitrous acid, by the muriatic acid, ſublimated. vitreous.	*Diaphoretic antimony.* *Powder of Algarotti.* *Flowers* or *ſnow of antimony.* *Glaſs of regulus of antimony.*	Grey / Red / Orange / Vitreous } Sulphurated oxide of antimony. Alkaline oxide of antimony.	*Grey calx of antimony.* *Kermes mineral.* *Golden ſulphur.* *Glaſs and liver of antimony.* *Rotrou's ſolvent.*	—	—	—	
	— —	—	—	—	—	Oxide of zinc. Sublimated oxide of zinc.	*Calx of zinc.* *Flowers of zinc, pompholix,* &c.	Sulphurated oxide of zinc.	*Precipitate of zinc by liver of ſulphur* or *factitious blende.*	—	—	—	
	— —	—	—	—	—	Black / Red } oxide of iron.	*Martial æthiops,* *Aſtringent ſaffron of Mars.*	Sulphurated oxide of iron.	— —	—	—	—	
-	— —	—	—	—	—	White oxide of tin.	*Calx,* or *putty of tin.*	Yellow ſulphurated oxide of tin.	*Aurum maſſivum.*	—	—	—	—
-	— —	—	—	—	—	White / Yellow / Red / Vitreous } oxide of lead.	*Ceruſe,* or *white lead.* *Maſſicot.* *Minium.* *Litharge.*	Sulphurated oxide of lead.	— —	—	—	—	—
	— —	—	—	—	—	Red / Green / Blue } oxide of copper.	*Brown calx of copper.* *Green calx of copper,* or *verdigris.* *Mountain blue.*	Ammoniacal oxide of copper.	— —	—	—	—	—
-	— —	—	—	—	—	Blackiſh / Yellow / Red } mercurial oxide.	*Æthiops* per ſe. *Turbith mineral.* *Precipitate* per ſe.	Black / Red { ſulphurated oxide of mercury.	*Æthiops mineral.* *Cinnabar.*	—	—	—	
-	— —	—	—	—	—	Oxide of ſilver.	*Calx of ſilver.*	Sulphurated oxide of ſilver.	— —	—	—	—	—
-	— —	—	—	—	—	Oxide of platina.	*Calx of platina.*	— —	— —	—	—	—	—
		—	—	—	—	Oxide of gold.	*Calx of gold.*	— —	— —	—	—	—	—
n.	*Vitrifiable earth, quartz,* &c.	—	—	—	—	— —	— —	— —	— —	—	—	—	—
rth.	*Clay,* or *earth of alum.*	—	—	—	—	— —	— —	— —	— —	—	—	—	—
-	*Terra ponderoſa.*	—	—	—	—	— —	— —	— —	— —	—	—	—	—
-	*Calcareous earth.*	—	—	—	—	— —	— —	— —	— —	—	—	—	—
-	— —	—	—	—	—	— —	— —	— —	— —	—	—	—	—
-	*Vegetable fixed alkali of tartar,* &c.	—	—	—	—	— —	— —	— —	— —	—	—	—	—
-	*Mineral alkali, marine alkali, natrum.*	—	—	—	—	— —	— —	— —	— —	—	—	—	—
-	*Fluor,* or *cauſtic volatile alkali.*	Ammoniacal gas.		*Alkaline gas.*		— —	— —	— —	— —	—	—	—	—

…es in the lower part of this col. cannot be reduced into a gazeous ſtate, and not only they, but ſeveral of thoſe in the upper part; we have therefore changed at this place the title of the column, and ſubſtituted another,

DENOMINATIONS newly appropriated to ſeveral Subſtances, which are more compound in their Nature, yet enter into new Combinations withou

	2	3	4	5	6	7	8	9	10		11		12	13	14
…ous …er.	Glutinous matter, *or* gluen.	Sugar.	Starch.	Fixed oil.	Volatile oil.	The aroma, *or* aromatous principle.	Reſin.	Extractive matter.	Extracto-reſinous matter.	{ in which the extractive matter predominates.	Reſinous extractive matter.	{ in which the reſin predominates.	Feculum.	Alcohol, *or* ſpirit of wine.	Alcohol { of potaſh. of guaiacum. of ſcammoneum. of myrrh, &c.
…age.	*Glutinous matter.*	*Saccharine matter.*	*Amylaceous matter.*	*Fat oil.*	*Eſſential oil.*	*Spiritus rector.*	*Reſin.*	*Extractive matter.*					*Feculum.*	*Spirit of wine.*	*Alkaline tincture.* *Tincture of guaiacum* —— *ſcammonium.* —— *myrrh,* &c.

T A B L E, ſhowing the Manner in which Natural Bodies, conſidered in a Chemical View, may be divided into Claſſes; with their ſeveral Subdiviſions; their Properties defined; and the Manner in which they are obtained, pointed out.

NATURAL BODIES, conſidered as the Objects of Chemiſtry, may be divided into the following Claſſes, viz. 1. SALTS. 2. EARTHS. 3. METALS. 4. INFLAMMABLES. 5. WATERS. 6. AIRS.

I. SALTS.

THESE are ſoluble in water, ſapid, and not inflammable. They are either ACIDS or ALKALIES.

I. *Acids* are diſtinguiſhed by turning ſyrup of violets red, or forming with alkalies neutral ſalts; and are ſuppoſed to conſiſt of dephlogiſticated air condenſed, as their acidifying principle. The different acids yet known are,

1. *Vitriolic, fixed.* The moſt ponderous of all fluids next to mercury, the moſt fixed in the fire, and the moſt powerful as a ſolvent of all the acids. Obtained chiefly from ſulphur by inflammation.
2. *Vitriolic, volatile.* Obtained alſo from ſulphur by inflammation; air being admitted during the proceſs. It acts leſs powerfully as a ſolvent than when in its fixed ſtate.
3. *Nitrous* or *Aquafortis:* a volatile fluid, generally met with of a reddiſh colour, and emitting noxious fumes, when in its concentrated ſtate; though this is found not to be eſſential to it, but owing to a mixture of phlogiſton. In its pure ſtate it is almoſt as colourleſs as water, and ſmokes very little. It is next in ſtrength to the vitriolic acid, and obtained chiefly from nitre. It conſiſts of dephlogiſticated and phlogiſticated air condenſed, and may be obtained by taking the electric ſpark for a long time in a mixture of theſe. By uniting with ſome metals it appears to be converted into volatile alkali.
4. *Muriatic,* or *ſpirit of ſea-ſalt.* A volatile fluid, generally of a fine yellow colour; though this alſo is owing to the admixture of foreign ſubſtances, generally of iron. Inferior in power to the former, and obtained from ſea-ſalt. Naturally this acid ſeems to be in an aerial ſtate, but eaſily contracts an union with water. On mixture with manganeſe, it is wholly converted into a yellow, and almoſt incondenſible vapour, called *dephlogiſticated ſpirit of ſalt*; but which, on mixture with inflammable air, recompoſes the marine acid.
5. *Fluor acid.* Obtained from a ſpecies of ſpar: has little acid power, but is remarkable for its property of corroding glaſs.
6. *Acid of borax,* or *ſedative ſalt.* Obtained from borax in the form of ſcaly cryſtals; found alſo naturally in ſome waters in Italy, and in certain minerals in other countries.
7. *Acetous acid.* Obtained by allowing any fermentable liquor to proceed in the fermentation till paſt the vinous ſtate. It is much leſs corroſive, and leſs powerful as a ſolvent, than the vitriolic, nitrous, or marine acids.
8. *Acid of tartar.* Procured from the hard ſubſtance called *tartar,* depoſited on the ſides of wine veſſels.
9. *Acid of ſugar.* Found naturally in the juice of ſorrel, and procured artificially by means of nitrous acid from ſugar and a great variety of other ſubſtances. Aſſumes a dry form.
10. *Acid of phoſphorus.* Obtained artificially from urine, and in large quantity from calcined bones; found naturally in ſome kinds of lead-ore; and in vaſt quantities in Spain united with calcareous earth. Aſſumes a ſolid form, and melts into glaſs.
11. *Acid of ants.* Procured from the animal from which it takes its name, by expreſſion or diſtillation, in a fluid form.
12. *Acid of amber.* Obtained in a ſolid form from amber.
13. *Acid of arſenic.* Obtained from that ſubſtance by means of nitrous acid. Is extremely fixed in the fire.
14. *Acid of molybdæna.* Procured from that ſubſtance by means of nitrous acid. Reſembles a fine white earth.
15. *Acid of lapis ponderoſus, tungſten,* or *wolfram.* Obtained as an acid, *per ſe,* from this ſubſtance by Mr Scheele; but its real acidity is denied by other chemiſts. Is in the form of a yellow powder.
16. *Acid of milk.* Obtained in a fluid form from that liquor.
17. *Acid of ſugar of milk.* Obtained in form of a white powder, by means of nitrous acid, from ſugar of milk.
18. *Lithiſiac acid* Obtained in a ſolid form from human calculus, by means of nitrous acid.
19. *Acid of benzoin.* Obtained in a ſolid form from that gum by ſublimation or lixiviation with quicklime.
20. *Acid of lemons.* Obtained from the juice of that fruit by cryſtallization.
21. *Sebaceous acid,* or *acid of fat.* Obtained in a fluid ſtate from ſuet by diſtillation.
22. *Acid of citrons.* Obtained in a fluid ſtate from the juice of that and other fruits.
23. *Acid of apples.* Obtained in a fluid ſtate from the juice of apples and other fruits.
24. *Acid of ſorrel.* Obtained in a ſolid form from the juice of that plant; the ſame with acid of ſugar.

II. *Alkalies.* Theſe turn ſyrup of violets green, and with acids form neutral ſalts. They are,

1. *Fixed vegetable,* or *Pot-aſh.* Always obtained from the aſhes of burnt vegetables. A deliqueſcent ſalt.
2. *Fixed foſſile.* A ſolid cryſtalline ſalt, ſometimes found native, as the natrum of Egypt; and ſometimes by burning ſea-weed as kelp.
3. *Volatile.* Obtained from ſal ammoniac, from the ſoot of burning bodies, and from the putrefactive fermentation. It is naturally in the ſtate of an inviſible and elaſtic vapour, conſtituting a ſpecies of aerial fluid, and conſiſts of phlogiſticated and inflammable air.

ACIDS, by their union with other bodies, form

Neutral Salts. Theſe are always compoſed of an acid and an alkali, and are of many different kinds, as may be ſeen in the following table.

Earthy Salts. Compoſed of an acid joined to an earthy baſis, as alum and gypſum. See the following table.

Metallic Salts. Formed of an acid and metal. The principal of theſe are vitriols; the others may be ſeen in the following table.

Essential Salts. Obtained from vegetables, and contain an acid joined with the juices of the plant in a particular manner not to be imitated by art. To theſe belong ſugar, manna, honey, and others of that ſort.

II. EARTHS.

These are ſolid bodies, not ſoluble in water, nor inflammable; and if fuſed in the fire, never reſume their earthy form again, but take that of glaſs. They are divided into *abſorbent*, *cryſtalline*, and *argillaceous*.

I. *Absorbent Earths* are capable of being united with acids, and are either calcareous, or not calcareous.

a, The calcareous abſorbent earths are,

1. *Limeſtone*, or *marble*. This is of infinite variety as to colour and texture. Marble is the hardeſt and fineſt. Thoſe kinds of limeſtone which feel unctuous to the touch, are generally impregnated with clay: thoſe that feel gritty, or where the lime is hard and weighty, contain ſand; this is the beſt for building; the other for manure.
2. *Chalk*. A white, friable, ſoft ſubſtance. This is much more free of heterogeneous matters than any limeſtone, and is eaſily calcined into quicklime. It is probably nothing elſe than limeſtone ſuddenly concreted without being cryſtallized.
3. *Sea ſhells*, are likewiſe a calcareous earth, and yield a very fine quicklime. Theſe are uſed in medicine.
4. *Terra ponderoſa*. A fine white earth ſometimes found combined with fixed air, but more commonly with the vitriolic acid; and forming with it a very heavy compound, named *ſpathum ponderoſum*. It is found in mines and veins of rocks.

b, The abſorbent earths which cannot be reduced into quicklime are,

1. *Magneſia alba*. A white earth, uſually found combined with the vitriolic acid, and forming bitter purging ſalt. It is likewiſe obtained from the mother-ley of nitre, the aſhes of burnt vegetables, *&c.*
2. *Earth of alum*. A particular kind of abſorbent earth, found in many places mixed with ſulphureous pyrites, as in Yorkſhire, &c. Clay of any kind may by a particular proceſs be converted into this earth.
3. *Earth of animals*. This is obtained by the calcination of animal ſubſtances, and by precipitation in the proceſs for making acid of milk. It can hardly be converted into glaſs; and is therefore uſed as a baſis for white enamels, &c. It is ſaid to conſiſt of the phoſphoric acid united to calcareous earth.

II *Crystalline or Vitrescent Earths*, are hard, and ſtrike fire with ſteel; may be calcined in the fire; but are not ſoluble in acids. Of this kind are,

1. *Sand* and *Flint*; found plentifully every where. With alkaline ſubſtances they are eaſily changed into glaſs; and hence are termed *vitreſcent*.
2. *Precious ſtones* of all kinds are likewiſe referable to this claſs; but they are of a much greater degree of hardneſs and tranſparency than the others.

III. *Argillaceous Earths* are digſtinguiſhed by acquiring a very hard conſiſtence when formed into a paſte with water, and expoſed to a conſiderable degree of heat; not ſoluble in acids. They are,

1. *Common clay*. It is of many different colours; but chiefly red, yellow, or white. The pureſt is that which burns white in the fire.
2. *Medical boles*. Theſe are of different ſorts; but are only a purer kind of clay, ſometimes mixed with a little iron or other matters.
3. *Lapis nephriticus*, or *ſteatite*. Theſe are indurated clays, found in various parts. They are at firſt ſoft and readily cut; but turn extremely hard in the air. Many other varieties of theſe earths might be mentioned; but as they do not differ in their chemical properties ſo much as in their external appearance, and being all mixed with one another, they more properly belong to the natural hiſtorian than the chemiſt.

III. METALLIC SUBSTANCES.

These are bodies of a hard and ſolid texture; fuſible in the fire, and reſuming their proper form afterwards; not miſcible with water, nor inflammable. They are divided into *Metals and Semimetals*.

I. *Metals* are malleable; and the ſpecies are,

1. *Gold*. The moſt ponderous and fixed in the fire of all bodies except platina, and the moſt ductile of any. It has a yellow colour, and is more commonly found in its metallic ſtate than any other metal. It has no proper ore; but is found in ores of ſilver, and almoſt all ſands contain ſome of it.
2. *Silver* is next to gold in malleability and ductility; but leſs fixed in the fire than either it or platina. It is ſometimes found in its native ſtate; but moſt commonly in that of an ore with ſulphur, ſometimes with arſenic, and aſſuming different appearances.
3. *Platina*. A white metal of a greater ſpecific gravity than gold, and altogether as fixed in the fire; the moſt difficult to be melted of all known ſubſtances; reſiſting the teſts which have uſually been applied for diſcovering the purity of gold, ſuppoſed from hence to be the *ſmiris* of the ancients. Found in South America.
4. *Copper*. Of a reddiſh colour, hard and ſonorous; admits of being extended greatly under the hammer, either hot or cold. Is difficult of fuſion. It is generally found in the ſtate of an ore with ſulphur. There are a great variety of ores of it, extremely beautiful, blue, red, green, and yellow.
5. *Iron*. A grey-coloured metal, extremely ductile when hot; the lighteſt of them all except tin. It is the only metal certainly known to admit of being welded; though platina is likewiſe ſaid to poſſeſs ſome ſhare of this property. It is likewiſe the only one capable of being tempered by cooling. It is found almoſt every where; and its ores are infinitely various.
6. *Tin*. A white ſoft metal, the lighteſt of the whole, and very ductile. The ores of it are generally arſenical, and aſſume a cryſtalline appearance; their colour being moſt uſually of a dark brown, and ſometimes very beautiful.

 7. *Lead*.

7. *Lead*. A metal of a dull bluiſh colour, exceedingly ſoft and malleable, and very weighty. Seldom found in its metallic ſtate, but uſually in an ore with ſulphur or arſenic; but ſeldom with ſulphur alone. The principal ores of it are the cubic, called *galena* and the glaſſy, called *ſpar*.

8. *Mercury or quickſilver*; formerly accounted a ſemimetal, on account of its fluidity, but now reckoned among the moſt perfect metals. It is a white, opaque, metallic body; fluid, except in a very intenſe degree of cold; very heavy, and eaſily volatilized by heat. Sometimes found in its fluid form, but uſually in a beautiful red ore with ſulphur, called *cinnabar*.

II. *Semimetals* are brittle, and do not ſtretch under the hammer. They are,

1. *Zinc*. A bluiſh white ſubſtance of a fibrous texture, conſiderably hard and ſonorous, with a ſmall degree of ductility; eaſily fuſed and volatilized. Its principal ore is lapis calaminaris.
2. *Biſmuth* or *tin-glaſs*. A white ponderous, hard, brittle and ſonorous body, of a plated texture; eaſily fuſed and vitrified. It is only reduced to an ore by arſenic. Its appearance much the ſame with regulus of antimony.
3. *Antimony*. A blackiſh ſubſtance, of a fibrous needle-like texture; hard, brittle, and of a conſiderable weight; not difficult of fuſion, and eaſily convertible into glaſs. Its only ore is with ſulphur, which is the crude antimony.
4. *Arſenic*. A bright, ſparkling, whitiſh-coloured ſemimetal; of a plated texture; very brittle, and extremely volatile. It is generally found in the ores of others metals.
5. *Cobalt*. A brittle ſemimetal fuſible in a moderate heat, and eaſily convertible into a beautiful blue glaſs, called *ſmalt*. It is always obtained from an arſenical ore, likewiſe called *cobalt*.
6. *Nickel*. A reddiſh white ſubſtance, of a cloſe texture, and very bright; eaſily melted, but very difficult to vitrify.

IV. INFLAMMABLE SUBSTANCES,

Are thoſe which continue to burn of themſelves when once ſet on fire. They are divided into *oils*, *ſulphur* or *brimſtone*, *alcohol* or *ardent ſpirits* and *charcoal*.

I. *Oils* are thickiſh, viſcous fluids, not miſcible with water. Divided into *animal*, *vegetable*, and *foſſile*.

a, *b*, The animal and vegetable oils are,

1. *Expreſſed*. Theſe are of a mild and bland taſte, inodorous, and not ſoluble in alcohol. They are obtained by expreſſion, as oil of olives, rape-ſeed, almonds, &c. Animal fats are of the ſame nature, as is alſo wax.
2. *Eſſential*. Theſe are always obtained by diſtillation, poſſeſs the taſte and flavour of the ſubject from whence they are drawn, and are ſoluble in alcohol. Of this kind are oil of cloves, ſpike, &c. The oil of ants is an example in the animal kingdom.
3. *Empyreumatic*. Theſe are obtained by a conſiderable degree of heat, and poſſeſs an acrid taſte and burnt-like flavour, as oil of hartſhorn. They are ſoluble in ſpirit of wine.

c. *Foſſile oils*. Theſe are found in the earth in their native ſtate; and are called, when pure, *naphtha*; which is of an acrid taſte, and extremely volatile, not miſcible with alcohol. A great many inflammable foſſils contain this, as bitumens, pit-coal, &c.

II. *Sulphur or Brimstone*. This is a dry friable ſubſtance, not miſcible with water. It is found in many mineral ſubſtances, metallic ores, &c. but is for the moſt part met with in pyrites. Great quantities of it are found in the neighbourhood of volcanoes.

III. *Alcohol or Ardent Spirits*. This is a fluid of an acrid and volatile nature, miſcible with water; obtained from fermented vegetable juices by diſtillation; as from the juice of the grape, malt-liquors, rice, &c.

IV. *Charcoal*. The reſiduum of moſt inflammable matters after undergoing diſtillation with a ſtrong fire. A black ſubſtance, acted upon with difficulty by acids; ſoluble in hepar-ſulphuris, and entirely diſſipable into inflammable air by a very violent heat. Of great uſe as fuel, and eſſentially neceſſary in metallurgy and other arts.

V. WATER.

A colourleſs inſipid fluid well known. It is either *ſimple* or *mineral*.

I. *Simple*, or *pure-rain-water*, as it called, though the moſt homogeneous fluid of this kind with which we are acquainted, is not perfectly pure, but always contains a portion of mucilaginous matter, which can never be perfectly ſeparated. It is ſuppoſed to conſiſt of dephlogiſticated and inflammable air condenſed.

II. *Mineral waters* are theſe ſpring-waters impregnated with ſaline ſubſtances; the diverſity of which is exceeding great; but they all agree in having an acid joined with them. The moſt common ſorts are impregnated with iron and ſulphur.

VI. AIR.

An inviſible and permanently elaſtic fluid, is of the following kinds: *Dephlogiſticated*, *phlogiſticated*, *fixed* or *fixable*, *inflammable*, *nitrous*, *vitriolic acid air*, *marine acid air*, *dephlogiſticated marine acid*, *alkaline air*, *hepatic air*, *atmoſpherical air*.

1. *Dephlogiſticated*. An elaſtic fluid naturally extricated in the proceſs of vegetation; artificially procured from nitre, minium, mangneſe, water, &c. eminently capable of ſupporting flame and animal life. One of the component parts of our atmoſphere.

2. *Phlogiſticated.* Produced in great quantities during the putrefactive fermentation; obtained alſo in the calcination of metals and other phlogiſtic proceſſes. Deſtroys animal life, and extinguiſhes flame, but is very friendly to vegetation. Is another of the component parts of our atmoſphere.
3. *Fixed*, or *fixable*. Has its name from the property of adhering to certain bodies, and fixing itſelf in them. Conſiſts of dephlogiſticated air united to charcoal. Is obtained by fermentation, and in all phlogiſtic proceſſes. Manifeſts the properties of an acid: extinguiſhes flame, and deſtroys animal life.
4. *Inflammable*. Conſiſts wholly of charcoal and a little water rarefied by heat; is remarkable for being the lighteſt of all gravitating ſubſtances. Is produced naturally in mines, and from putrid waters; artificially procured from certain metallic ſolutions, by paſſing the ſteam of water over red-hot iron; by diſtilling wood, pit-coal, &c. with a ſtrong heat; or by expoſing charcoal to the heat of a burning lens *in vacuo*. It extinguiſhes flame unleſs it be mixed with a certain proportion of atmoſpherical or dephlogiſticated air; in which caſe it explodes violently, deſtroys animal life, but is friendly to vegetation.
5. *Nitrous*. Procured artificially in diſſolving metallic or other ſubſtances in the nitrous acid. On mixture with dephlogiſticated air both the fluids loſe their elaſticity, and a ſmall quantity of nitrous acid is produced. It inſtantly kills animals, and extinguiſhes flame. By union with ſome metals is converted into volatile alkali. In ſome caſes it may be made to ſupport flame, and even animal life. Its property of condenſing along with phlogiſticated air renders it a teſt of the ſalubrity of the atmoſphere.
6. *Vitriolic acid air*. The ſame with volatile or ſulphureous vitriolic acid.
7. *Marine acid air*. The ſame with marine acid reduced into vapour, and deprived of moſt of its water.
8. *Dephlogiſticated marine acid*. Suppoſed by ſome to be the marine acid deprived of its phlogiſtion; by others to be the ſame acid with an addition of pure air. It deſtroys many kinds of colours; whitens linen, and with inflammable air regenerates common marine acid.
9. *Alkaline air*. The ſame with pure volatile alkali; is formed by an union of phlogiſticated and inflammable air.
10. *Hepatic air*. Produced from the decompoſition of liver of ſulphur by acids, or in the common atmoſphere. It is inflammable, but does not burn with exploſion.
11. *Atmoſpherical air*. Compoſed of dephlogiſticated and phlogiſticated air; and thus ſupports both animal life and vegetation.

TABLE, ſhowing the ſeveral Combinations that the SIMPLE CHEMICAL ELEMENTARY BODIES admit of with one another; the Compound reſulting from that Mixture; and the Manner in which the Union is effected: With ſome Account of the principal Uſes to which theſe are applied in Arts or Manufactures.

N. B. This mark*, put above any word, denotes that there is ſome difficulty in the proceſs, or that the union is not very complete.

VITRIOLIC ACID may be combined with the following ſubſtances, viz.

ACIDS.
- NITROUS ACID. A mixture which readily inflames oils. By ſolution, generating heat.
- MURIATIC, VEGETABLE, and all other ACIDS yet known. By ſolution, generating heat. But theſe mixtures are applied to no particular uſe in medicine or arts.

ALKALIES.
- VEGETABLE.
  - *Vitriolated tartar*. By ſolution and cryſtallization, or double elective attraction from a great variety of bodies.
  - *Nitrum vitriolatum*. A vitriolated tartar, obtained by diſtilling from nitre with the vitriolic acid.
  - *Sal polychreſtum*. By deflagrating nitre with ſulphur. There are many other kinds of vitriolated tartar, known formerly by different names, and ſuppoſed to be poſſeſſed of particular properties, but they are now neglected.
- FOSSILE. *Glauber's ſalt*. By ſolution and cryſtallization. Much uſed in medicine as a gentle purgative.
- VOLATILE. *Secret ammoniac*. By ſolution. Formerly ſuppoſed a moſt powerful menſtruum for metals, &c. but without any juſt foundation.

EARTHS.
- CALCAREOUS EARTHS.
  - A corroded calx. By ſimple corroſion. This when perfectly edulcorated with water is found to be a true gypſum.
  - *Selenites*. By precipitation from a very dilute ſolution of chalk in the nitrous acid, by means of the vitriolic acid.
  - *Terra ponderoſa*. With this it unites in preference to alkalies, forming a very heavy and inſoluble ſubſtance called *ſpathum ponderoſum*.
  - *Gypſum* or *Paris-plaſter*. Often found in a native ſtate. May be artificially formed by precipitating from a ſolution of chalk in a very concentrated nitrous acid. Uſed as a cement: for taking impreſſions from medals, &c.
  - *Talc aſbeſtos, &c.* A native production which connot be perfectly imitated by art. Uſed for holding objects in microſcopes, making incombuſtible cloth, &c.
- MAGNESIA. *Epſom*, or *magneſia Glauber's ſalt*. By ſolution and cryſtallization. Much uſed in medicine for the ſame purpoſes as real Glauber's ſalt.

EARTHS.

- EARTH of ALUM. *Alum.* By ſolution, cryſtallization, &c. Uſed by dyers as a preparatory for taking on the colours, papermakers, goldſmiths, &c.
- EARTH of ANIMALS, OSTEOCELLA, &c. By ſolution. The mixtures of theſe are not applied to any particular uſe.
- CLAY*. *Alum.* By digeſting pure clay for ſome time in this acid, and expoſing it for ſome time to the air, an alum is produced; and if the clay is precipitated from this aluminous concrete, it is found to be a pure earth of alum, ſoluble in all acids.
- FLINT. A thickiſh coagulum. By digeſting the liquor ſilices in the vitriolic acid.

METALS.

- GOLD*. Imperfectly. By a particular proceſs after being ſeparated from aqua-regia.
- SILVER*. By ſolution, after it has been precipitated from the nitrous acid by alkalies. The fumes which ariſe in this ſolution are inflammable.
- COPPER. *Blue vitriol.* This is ſometimes a native production, but in this way it is never pure. It is artificially prepared by ſolution in a very concentrated acid, and cryſtallizing it.
- IRON.
  - *Green vitriol* or *copperas.* Obtained at large by particular proceſs from pyrites; or by ſolution, &c. in a diluted acid. This is the baſis of all black dyes, ink, &c. as it ſtrikes a black colour with vegetable aſtringents.
  - *Salt of ſteel.* By calcining the cryſtals of green vitriol till they are converted into a white powder.
  - *Colcothar of vitriol.* By continuing the calcination till it aſſumes a brown colour.
- LEAD.
  - *Saturnus vitriolicus.* A ſolution in a boiling heat, but is again precipitated when cold.
  - An indiſſoluble concrete. By precipitation from the nitrous acid.
- TIN. *Jupiter corroſivus.* By a boiling heat in a concentrated acid.
- MERCURY.
  - *Ignis Gehenne*, or infernalis of Paracelſus. By a boiling heat, and repeated coctions with freſh acid when it is evaporated.
  - *Turpeth mineral*, or mercurius precipitatus flavus. By evaporating to dryneſs, and then waſhing with water.

SEMIMETALS.

- ANTIMONY*. *A metallic ſalt.* By elective attraction from butter of antimony.
- ZINC. *White vitriol.* Often found in its native ſtate. Artificially made by ſolution and cryſtallization in a diluted acid. Uſed by painters for drying.
- BISMUTH. A corroded calx. By ſolution in a concentrated acid.
- ARSENIC - - - By ditto.
- COBALT. A roſe-coloured mixture. By ſolution. If this is precipitated by a fixed alkali, and again diſſolved, the liquor appears of a beautiful red.

OILS.

- EXPRESSED. A blackiſh gummy-like maſs. By ſolution, generating a conſiderable heat. Native gums are ſuppoſed to owe their origin to a mixture of this kind.
- ESSENTIAL. A dark-coloured reſinous maſs. A great heat and violent effervеſcence being produced by this mixture. Native reſins ſuppoſed the ſame.
- EMPYREUMATIC. Little known. By ſolution.
- FOSSILE. A ſubſtance reſembling amber. By ſolution.

SULPHUR*. Here there is no proper union of ſubſtances; but if ſulphur is boiled in this acid, it becomes leſs inflammable and more fixed than any ordinary ſulphur.

ALCOHOL.

- *Vitriolic ether.* By careful ſolution and diſtillation, the ether being ſeparated by the addition of water.
- *Spiritus vitrioli dulcis.* By ſolution and diſtillation.
- *Oleum dulce.* By continuing the heat after the ether has ariſen.
- *Oleum anodynum minerale.* By rediſtilling the reſiduum of the laſt with alcohol. A medicine much celebrated by Hoffman.
- *Sulphur.* By puſhing the heat after the oil comes over. It is to be obſerved that this is produced in every combination of this acid with inflammables or metals.

WATER. An acidulated water. Sometimes, though ſeldom, found iſſuing along with native ſprings. Applied to no particular uſe.

NITROUS ACID may be combined with the following Subſtances, viz.

ACIDS.

- VITRIOLIC, as above.
- MURIATIC. *Aqua-regia.* By ſolution. This is the only proper menſtruum for gold; and it is a ſolution of tin in this menſtruum which is the baſis of the ſcarlet dye.
- VEGETABLE, and all others. By ditto. Theſe compounds have no particular names, nor are applied to any particular uſes in medicine or arts.

ALKALIES.

- VEGETABLE. *Common nitre.* A native production. Made artificially by ſolution and cryſtallization. This deflagrates with oily or metallic bodies, and is the foundation of gun-powder.
- FOSSILE. *Cubic nitre.* By ſolution.
- VOLATILE. *Nitrous ammoniac.* By ſolution. This differs from all the other ammonical ſalts, by being ſoluble in alcohol.

EARTHS.

- CALCAREOUS.
  - *Deliqueſcent cryſtals.* By ditto and cryſtallization.
  - *Baldwin's phoſphorus.* By ditto and evaporating to dryneſs.
- EARTH of ALUM, and all other abſorbent earths. By ſolution. The compounds have no names nor any remarkable properties hitherto diſcovered.
- CRYSTALLINE EARTHS*. By ſolution after precipitation from the liquor ſilices.

METALS.

- GOLD*. *Slightly impregnated.* By a boiling heat in cloſe veſſels, after the ordinary method of ſeparating ſilver from gold by the nitrous acid. It ſpontaneouſly ſubſides in the air.
- SILVER.
  - *A fluid ſolution.* By ſolution. This when diluted with water ſtains hair and bones black; as alſo marble, agate, jaſper, &c. of different colours.
  - *Sal metallorum.* By ſolution and cryſtallization.
  - *Catharticum lunare, lunar cauſtic*, or *lapis infernalis.* By inſpiſſating the ſolution to dryneſs.
- COPPER. A green-coloured ſolution. By ſolution.
- IRON. A greeniſh ſolution, if a diluted acid is employed; if otherwiſe, it is of a yellowiſh colour: evaporated to dryneſs, it deliquates in the air.
- LEAD.
  - A yellow ſolution. By diſſolving in a diluted acid. If much water is added, the metal is precipitated.
  - *Saturni fulminans.* By inſpiſſating the ſolution. This explodes when put upon the fire with greater force than nitre, and has been propoſed to be uſed as an ingredient in gun-powder to augment its force.
- TIN. A ſolution or corroded calx. By a careful ſolution without heat it remains ſuſpended; if otherwiſe, it falls down in form of a calx. This is commonly ſuppoſed to be the compoſition uſed in dyeing ſcarlet; but by miſtake: for it is a ſolution of tin in aqua-regia that communicates that fine colour to cochineal. The ſame ſolution is the baſis of the powder which tinges glaſs of a ruby colour. It is the precipitate of gold from aqua-regia by means of tin.
- MERCURY.
  - A limpid ſolution, intenſely corroſive. By ſolution.
  - *Red precipitate.* By evaporating the ſolution to dryneſs, and then calcining till it becomes red.
  - *Mercurius corroſivus fuſus.* By precipitating from the nitrous acid by fixed alkali.
  - *White precipitate* - By ditto with the volatile alkali.

SEMIMETALS.

- BISMUTH.
  - A greeniſh ſolution. By uſing a concentrated acid. This might be applied in ſome caſes in the art of dyeing; but is not yet come into general uſe.
  - *Magiſtery of biſmuth.* By precipitating from the ſolution by means of water. This has been employed as a coſmetic, but is inefficacious and unſafe. If mixed with pomatum, this ſtains hair of a dark colour without injuring it.
- ZINC. A corroded ſolution. By the ordinary means.
- ANTIMONY.
  - A colourleſs calx. By ſimple corroſion.
  - *Bezoardic mineral.* By diſtilling from butter of antimony, after having added the nitrous acid.
  - *Antimonium diaphoreticum.* By adding nitre to crude antimony, and deflagrating.
  - *Ceruſa antimonii.* By deflagrating regulus of antimony with nitre.
- COBALT.
  - A red liquor. By ſolution either in its calcined or metallic ſtate.
  - *Roſe-coloured cryſtals.* By adding muriatic acid, and allowing it to cryſtallize.
  - *Green ſympathetic ink.* By diſſolving theſe cryſtals in water. The ſolution is red when cold, and green when warm; when wrote with, it diſappears when dry; but when held to the fire it becomes green; and again diſappears when cold.
- NICKEL. A green-coloured liquor. By ſolution.

OILS.

- EXPRESSED. A thick bituminous-like ſubſtance. Upon the mixture a conſiderable degree of heat is generated, and ſometimes, though very ſeldom, actual flame is produced.
- ESSENTIAL. Ditto. A more violent heat is generated upon the mixture with theſe oils than any other, and with many of them an actual flame is produced.
- EMPYREUMATIC. This mixture has no name, nor is it applied to any remarkable uſe in arts.
- FOSSILE. Ditto.

ALCOHOL.

- *Nitrous ether.* By digeſting; the ether ariſing to the ſurface.
- *Spiritus nitri dulcis.* By digeſting a little, and then diſtilling.

WATER. *Acidulated water.* By ſolution.

The MURIATIC ACID may be combined with the following Subſtances. viz.

ACIDS.

- VITRIOLIC and NITROUS. As in the former part of this Table.
- VEGETABLE, and all others yet known. By ſolution: but as none of theſe mixtures are applied to any particular purpoſe, we take no notice of them.

ALKALIES.

- VEGETABLE. *Digeſtive ſalt.* By ſolution and cryſtallization.
- FOSSILE.
  - *Common ſalt.* Commonly obtained by evaporating ſea-water to dryneſs; or artificially made by mixing the acid and alkali, and cryſtallizing.
  - *Sal gem.* A native foſſile ſalt, found in mines in Poland, Spain, &c. of the ſame nature as common ſalt, but more pure.
- VOLATILE. *Common ammoniac.* Obtained at large by a particular proceſs from ſoot. Artificially made by mixing the acid and alkali, and cryſtallizing.

EARTHS.

- CALCAREOUS.
  - *Liquid ſhell.* By ſolution. A ſubſtance whoſe effects in medicine have been greatly extolled.
  - *Ol. calcis per deliquium.* By evaporating liquid ſhell to dryneſs. It naturally deliqueſces.
  - *Fixed ammoniac.* By ſolution and cryſtallization. This ſometimes appears luminous in the dark when ſtruck with a hammer.
- OSTEOCELLA, MAGNESIA, and other abſorbents. By ſolution: but the properties or uſes of theſe are not known.

METALS.

- GOLD*, *A yellow liquor.* By boiling a calx of gold (in whatever way obtained) in this acid. It does not act upon it in its metallic ſtate.
- SILVER*.
  - *A fluid ſolution.* By diſſolving the ore of ſilver in this acid. It does not act upon pure metallic ſilver.
  - *Luna cornea.* By elective attraction from the nitrous acid.
- PLATINA*. A fluid ſolution. With difficulty effected, after having been precipitated from aqua-regia by alkalies.
- COPPER. *A green deliqueſcent inflammable ſalt.* By ſolution and inſpiſſating to dryneſs.
- IRON. *Tinctura martis aurea.* By ſolution. The iron is in ſome meaſure rendered volatile by the operation.
- LEAD.
  - A limpid ſolution. By a boiling heat, and frequent cohobations with freſh acid.
  - *Cornea Saturni.* By precipitation from the nitrous acid.
- TIN*.
  - A corroded powder. By ſimple corroſion.
  - *Butter of tin.* By diſtilling from corroſive ſublimate.
- MERCURY*.
  - A colourleſs cryſtalline maſs, extremely acrid. By corroſion, employing the fumes of a very concentrated acid.
  - *Mercur. corroſiv. albus.* By precipitation from the nitrous acid.
  - *Corroſive ſublimate.* By ſubliming from ſal ammoniac, common ſalt, or many other bodies.
  - *Mercurius dulcis.* By reſubliming corroſive ſublimate with more quickſilver.
  - *Mercurial panacea.* By ſubliming corr. ſub. nine times, and digeſting for ſome time in ſpirit of wine.

SEMIMETALS.

- BISMUTH*. A ſolution very ſlightly impregnated. By employing a very concentrated acid.
- ZINC. A ſolution of a very ſlight yellow colour.
- ARSENIC*. *Butter of arſenic.* By diſtilling corroſive ſublimate with arſenic; the arſenic uniting with the acid, and leaving the mercury.
- COBALT. A reddiſh ſolution. By the ordinary means. It becomes green by a gentle heat.
- NICKEL. A green ſolution. By the ordinary means.

OILS*. By ſolution. The union here is but imperfect, nor have they any particular name.

ALCOHOL. *Spiritus ſalis dulcis.* By digeſtion, and afterwards diſtilling. The acid here is never totally dulcified.

WATER. *Acidulated water.* Generating heat by mixture.

VINEGAR may be combined with the following Subſtances, viz.

ACIDS. VITRIOLIC, NITROUS, and MURIATIC, as in the above table. It likewiſe unites with all other acids, generating heat; but the properties or uſes of theſe are not known.

ALKALIES.

- VEGETABLE. *Regenerated tartar.* By ſolution and cryſtallization.
- FOSSILE. *Polychreſt of Rochelle.* By ditto.
- VOLATILE. *Spiritus Mindereri* By ſolution.

EARTHS.

- CALCAREOUS EARTH. *Earthy ſalts.* Not known in medicine or arts.
- MAGNESIA. *Dr Black's purging ſalt.* By ſolution. It unites with all the other abſorbent earths; but the properties of theſe mixts are unknown.

METALS.

- COPPER. *Verdegris.* By ſolution and cryſtallization; or at large, by ſtratifying copper-plates with the huſks of the grape.
- IRON. *Sal martis aperiens.* By ſolution and cryſtallization.
- LEAD.
  - *Ceruſe.* By expoſing, in certain circumſtances, thin plates of lead to the fumes of vinegar.
  - *Saccharum Saturni.* By ſolution and cryſtallization.
- TIN*. This is not properly diſſolved; but the acid is evidently impregnated. By the ordinary means of ſolution.
- MERCURY*.
  - *A fluid ſolution.* By employing a precipitate of mercury from the nitrous acid by alkalies.
  - *A red calx.* By long digeſtion with fluid mercury.

SEMIMETALS.

- ZINC. A colourleſs ſolution of a ſweetiſh taſte. By digeſting for ſome time.
- ANTIMONY*. *Vinum benedictum.* This it not a proper ſolution of the metal, but the acid is impregnated with an emetic quality.
- ARSENIC. *Vinum arſenicum.* By ditto. A curious phoſphoric liquor.
- BISMUTH. An auſtere ſtyptic liquor. By ſtrong coction.

OILS*. The union here is imperfect, nor have any of them obtained particular names.

ALCOHOL. A mixture much uſed for anointing ſprains, &c.

WATER. *Acidulated water.*

ACID OF TARTAR may be combined with the following ſubſtances, viz.

ALKALIES.

- VEGETABLE.
  - Cream of tartar with exceſs of acid.
  - Soluble tartar, when completely ſaturated.

ALKALIES.

- FOSSILE. Rochelle ſalt.
- VOLATILE.
  - A ſalt very difficult of ſolution with exceſs of acid.
  - A beautiful and ſoluble ſalt when perfectly ſaturated.

EARTH.

EARTH.	Calcareous. An indiſſoluble ſelenite.
METALS.	Copper. A fine green colour for painting.
	Iron. A green aſtringent liquid. Chalybeated tartar.
SEMIMETAL.	Regulus of Antimony. Emetic tartar.

ACID of URINE may be combined with the following ſubſtances, viz.

ACIDS of all kinds.	The nature of theſe not known.
ALKALI.	Fixed Vegetable. A ſalt not eaſily cryſtallized, the nature of which is not known.
	Fossile. A fine cryſtallized ſalt uſed in medicine.
	Volatile. A glaſs-like ſaline ſubſtance called *microcoſmic ſalt*. The acid is always found in this ſtate by evaporating urine.
VITRESCENT EARTHS.	A glaſs of different ſorts. By fuſion.
METALS.	Lead. An inflammable malleable maſs. By calcining the dry ſalt with lead.
	Tin. A maſs reſembling zinc; and inflammable. By ditto.
	Iron. A true *phoſphorus*. By ditto.
	Iron. A bluiſh ſolution. By employing a watery ſolution of the acid.
	Copper. A corroded powder, or green ſolution. By a boiling heat in a watery ſolution of the acid.
	Mercury. A ſemi-opaque maſs. By fuſion with the acid, in its ſolid form.
SEMIMETALS.	Zinc. A corroded powder, ſoluble in water. By ſolution in the acid in a watery ſituation.
	Zinc. A true *phoſphorus*. By fuſion with the dry acid.
	Antimony. A ſolution in the ordinary way.
	Antimony. A brilliant ſtriated maſs. By fuſion with the dry acid.
	Bismuth. A mixture but little changed in appearance from ordinary biſmuth. By fuſion.
	Arsenic. A whitiſh ſemitranſparent deliqueſcent maſs. By fuſion.
	Cobalt. A reddiſh tincture. By ſolution.
OILS.	*Baldwin's phoſphorus*. By diſtilling with ſubſtances that contain oils or inflammable matter.

FLUOR ACID, may be combined with the following Subſtances, viz.

ALKALIES.	Fixed Vegetable. A gelatinous ſaline maſs which cannot be cryſtallized. Great part of it is alſo diſſipated by evaporation to dryneſs.
	Fossile. A ſubſtance ſimilar to the foregoing.
	Volatile. Lets fall a quantity of ſiliceous earth, and forms a cryſtallizable ammoniacal ſalt.
EARTHS.	Lime, Magnesia, Earth of Alum. A gelatinous matter.
	Siliceous Earth. After long ſtanding, cryſtals of quartz.
METALS.	Silver, Quicksilver. The calces of theſe metals partially diſſolved; but the properties of the ſolution unknown
	Copper. The calx eaſily ſoluble, and affording blue cryſtals; the metal only partially ſo.
	Iron. Diſſolved with violence with the emiſſion of inflammable vapours into an uncryſtallizable liquor.

ACID of SUGAR may be combined with the following Subſtances, viz.

ALKALIES.	Fixed Vegetable. A ſalt ſcarce capable of cryſtallization when perfectly neutral.
	Fossile. A ſalt difficultly ſoluble in water.
	Volatile. An ammoniacal ſalt ſhooting into quadrangular priſms.
EARTHS.	Lime. A kind of ſelenite from which the acid cannot be ſeparated by a burning heat.
	Terra Ponderosa. A ſalt formed into angular cryſtals, ſcarce ſoluble in water.
	Magnesia. A white powder inſoluble without an exceſs of acid.
	Earth of Alum. A yellow pellucid maſs incapable of cryſtallization, and liquefying in the air.
METALS.	Gold, Silver, Platina, Quicksilver. The calces of all theſe metals diſſolved, but the nitre of the ſolutions unknown.
	Iron. Diſſolved in great quantity, and forming a yellow priſmatic ſalt eaſily ſoluble in water.
SEMIMETAL.	Cobalt. A yellow-coloured ſalt forming a ſympathetic ink with ſea-ſalt.
INFLAMMABLES.	Alcohol. An ether which cannot eaſily be ſet on fire unleſs previouſly heated, and burning with a blue flame.

ACID of BORAX or SEDATIVE SALT may be combined with the following Subſtances, viz.

ALKALIES.	Fossile. *Borax*. A native ſubſtance, which may be imitated by art. It is of great uſe in promoting the fuſion of metals and earths.
	Volatile. An ammoniacal ſalt ſhooting into ſmall cryſtals, and melting by an intenſe heat into a greyiſh-coloured glaſs.
EARTHS.	Magnesia. A ſalt cryſtallizable in vinegar and acid of ants. Decompoſed by other acids and ſpirit of wine.
	Earth of Alum. In certain proportions a ſalt difficult of ſolution; in others a hard maſs reſembling pumice-ſtone, yet partially ſoluble in water.

METALS.

METAL. Iron. An amber-coloured ſolution yielding cryſtals of a yellow colour.
SEMIMETAL. Arsenic. A cryſtallizable compound ſhooting into pointed ramifications, or forming a greyiſh, white, or yellow powder.
ALCOHOL. A ſolution with a conſiderable heat, which burns with a green flame.
WATER. A ſolution in a conſiderable heat. The other mixtures with this acid not known.

ACID of AMBER may be combined with the following Subſtances, viz.

ALKALIES.
- Fixed Vegetable. A tranſparent and cryſtallizable ſalt, but deliqueſcent.
- Fossile. A cryſtallizable ſalt not deliqueſcent.
- Volatile. An ammoniacal ſalt ſhooting into acicular cryſtals.

EARTHS.
- Lime. A cryſtallizable ſalt, difficult of ſolution and not deliqueſcent. Decompoſed by common ſal ammoniac.
- Magnesia. A gummy deliqueſcent ſaline maſs, not cryſtallizable.
- Earth of Alum. A priſmatic ſalt incapable of decompoſition by alkalies.

METALS.
- Silver. A ſalt ſhooting into thin oblong cryſtals obtained from the precipitate; but no ſolution of the perfect metal.
- Copper. A cryſtallizable ſalt of a green colour.
- Iron. A cryſtallizable ſalt of a brown colour.
- Tin. A cryſtallizable ſalt from the precipitate, ſcarce to be decompoſed by alkalies.
- Lead. A cryſtallizable ſalt from the precipitate.

SEMIMETALS.
- Zinc. A cryſtallizable ſalt.
- Bismuth. A cryſtallizable ſalt from the precipitate, not to be decompoſed by alkalies.
- Regulus of Antimony. A ſolution of the precipitate.

ACID of ANTS may be combined with the following Subſtances, viz.

ALKALIES.
- Fixed Vegetable. A cryſtallizable ſalt, deliqueſcent in the air.
- Fossile. A ſalt of a ſimilar nature.
- Volatile. An ammoniacal liquor, cryſtallizable with difficulty.

EARTHS.
- Chalk or Coral. A cryſtallizable ſalt which does not deliquate.
- Magnesia. A ſaline liquor ſcarcely cryſtallizable.
- Terra Ponderosa. A cryſtallizable ſalt which does not deliqueſce.
- Earth of Alum. Unites with difficulty, and ſcarcely to the point of ſaturation. The nature of the compound not known.

METALS.
- Silver*. By ſolution. The calx of ſilver precipitated from aquafortis by alkalies; but does not act upon it in its metallic ſtate.
- Copper. Beautiful green cryſtals. By diſſolving and cryſtallizing calcined copper. It acts ſlowly upon it in its metallic ſtate.
- Iron. A cryſtallizable ſalt. It diſſolves this metal with great facility.
- Lead*. A ſalt reſembling ſaccharum ſaturni. By diſſolving the red calx of lead. But it does not act upon it in its metallic ſtate.

SEMIMETAL. Zinc. Elegant cryſtals. By the ordinary means.

The effects of this acid upon other bodies, or the uſes to which theſe combinations might be applied, are not yet ſufficiently known.

ACID of ARSENIC may be combined with the following Subſtances, viz.

ALKALIES.
- Fixed Vegetable. A ponderous ſalt ſhooting into fine cryſtals by ſuperſaturation with acid.
- Fossile. A ſalt cryſtallizable when perfectly neutral.
- Volatile. A peculiar kind of ammoniacal ſalt parting with the alkali, and decompoſing ſome of it in a ſtrong fire.

EARTHS.
- Chalk. A cryſtallizable ſalt ſcarcely ſoluble.
- Magnesia. A gelatinous maſs which cannot be cryſtallized.
- Terra Ponderosa. An inſoluble white powder.

METALS.
- Copper. A green-coloured ſolution.
- Iron. A very thick gelatinous ſolution.
- Lead. A ſolution which cannot be cryſtallized.
- Tin. A gelatinous ſolution in the moiſt way. A mixture taking fire in cloſe veſſels in the dry way.

SEMIMETALS.
- Zinc. A ſolution in the moiſt way, and in the dry, a mixture taking fire in cloſe veſſels.
- Bismuth. A partial ſolution.
- Regulus of Antimony. A partial ſolution.
- Cobalt. A partial ſolution of a red colour.
- Manganese. A partial ſolution in its natural ſtate. When the manganeſe is phlogiſticated, a cryſtallizable ſalt may be obtained.

INFLAMMABLES.
- Charcoal. A mixture taking fire and ſubliming when heated in cloſe veſſels.
- Oil of Turpentine, &c. A thick black ſubſtance after ſome days digeſtion.
- Sulphur. A red ſublimate.

ACID or MOLYBDÆNA may be united with the following Substances, viz.

ALKALI.	FIXED VEGETABLE. A cryſtallizable ſalt.
	VOLATILE. A neutral ſalt, the nature of which is unknown.

ACID or MILK may be combined with the following Subſtances, viz.

ALKALIES.	FIXED VEGETABLE. A deliqueſcent ſalt ſoluble in alcohol.
	FOSSILE. A ſalt of a ſimilar nature.
	VOLATILE. A deliqueſcent ſalt parting with much of the alkali by heat.
EARTHS.	CALCAREOUS and ARGILLACEOUS. Deliqueſcent ſalts.
	MAGNESIA. A ſalt more eaſily cryſtallized, but deliqueſcent.
METALS.	COPPER. A blue ſolution, which cannot be cryſtallized.
	IRON. A brown ſolution, with the emiſſion of inflammable air, yielding no cryſtals.
	LEAD. An aſtringent ſweetiſh ſolution, which does not cryſtallize.
SEMIMETAL.	ZINC. A cryſtallizable ſalt, with the emiſſion of inflammable air during the ſolution.

ACID or SUGAR or MILK may be combined with the following Subſtances, viz.

ALKALIES.	FIXED VEGETABLE. A ſalt very difficult of ſolution.
	FOSSILE. A ſalt more eaſily ſoluble.
	VOLATILE. A peculiar kind of ammoniac.
EARTHS.	ABSORBENT and ARGILLACEOUS. Inſoluble ſalts.

ACID or APPLES may be combined with the following Subſtances, viz.

ALKALIES.	FIXED VEGETABLE, FOSSILE, and VOLATILE. Deliqueſcent ſalts.
EARTHS.	CALCAREOUS. A ſalt difficult of ſolution unleſs the acid prevail.
	MAGNESIA. A deliqueſcent ſalt.
	EARTH of ALUM. A ſalt very difficult of ſolution.
METAL.	IRON. A brown ſolution, which does not cryſtallize.
SEMIMETAL.	ZINC. A fine cryſtallizable ſalt.

ACID or FAT may be combined with the following Subſtances, viz.

ALKALIES.	FIXED, VEGETABLE, and FOSSILE. Neutral ſalts of a particular nature.
	VOLATILE. A concrete volatile ſalt.
EARTHS.	CALCAREOUS. A cryſtallizable ſalt of a brown colour.
	MAGNESIA. EARTH of ALUM. } A gummy maſs, which refuſes to cryſtallize.
METALS.	SILVER. A ſolution of the calx.
	PLATINA. The calx copiouſly diſſolved, and even the perfect metal attacked by diſtillation to dryneſs.
	COPPER. A green ſolution, which cannot be cryſtallized.
	IRON. A cryſtallizable ſalt, which does not deliquate.
	LEAD. An aſtringent ſolution of the red calx called *minium*.
	TIN. A ſolution in ſmall quantity.
	MERCURY. A ſolution by being twice diſtilled from the metal.
SEMIMETALS.	ZINC. Diſſolved in its metalline ſtate.
	BISMUTH. A ſolution of precipitate.
	REGULUS of ANTIMONY. A cryſtallizable ſalt, which does not deliquate.
	MANGANESE. A perfect and clear ſolution.

ACID or BENZOIN may be combined with the following Subſtances, viz.

ALKALIES.	FIXED VEGETABLE. A ſalt ſhooting into pointed feathery cryſtals.
	FOSSILE. A ſalt procurable in larger cryſtals.
	VOLATILE. A deliqueſcent ſalt ſcarce cryſtallizable.
EARTHS.	CALCAREOUS. A cryſtallizable ſalt not eaſily ſoluble.
	MAGNESIA. A cryſtallizable ſalt eaſily ſoluble.

The FIXED ALKALI, whether VEGETABLE or FOSSILE, can be united with the following Bodies; but the Vegetable is beſt known.

ACIDS; Vitriolic, Nitrous, Muriatic, Vegetable; and acid of Urine, of Amber, of Ants, of Borax, &c. as in the former part of this Table.

ALKALIES of all ſorts. The uſes of theſe mixtures are not known.

EARTHS.	CRYSTALLINE. *Liquor ſilicum*. By fuſion with twice their weight of alkali.
	CRYSTALLINE. *Glaſs*. By fuſion with a much ſmaller proportion of alkali. This is the compoſition of cryſtal glaſs, and all others commonly uſed.
	ABSORBENTS. Argillaceous, and all kinds of earths. *Glaſs*. By fuſion; differing in quality according to the nature of the ingredients. Glaſs is likwiſe produced with it in fuſion with metals.
METALS.	GOLD*. After having precipitated it from aqua-regia, it diſſolves it if the alkali has been calcined with animal ſubſtances.
	SILVER*. After having precipitated it from the nitrous acid, it diſſolves it if the alkali has been calcined in contact with the flame.

METALS.

- Tin. A corroded powder. By the ordinary means of folution.
- Copper. By ditto.
- Lead. A fluid folution. By ditto. This ftains hair black.
- Iron*. A blood-coloured folution. By dropping a folution of iron in the nitrous acid, into an alkaline lixivium.
- Mercury*. A fluid folution. After precipitating it from acids; if the alkali is in too large proportions, it then diffolves it, efpecially if the alkali has been calcined in contact with the flame.

SEMIMETALS.

- Zinc*. By folution, after having precipitated it from the nitrous acid.
- Bismuth*. By folution, after having precipitated it from the nitrous acid.
- Antimony.
  - *Kermes mineral.* By diffolving antimony in an alkaline lixivium, filtering, and allowing it to ftand in a cool place till it precipitates.
  - *Golden fulphur of antimony.* By diffolving a crude antimony in an alkaline lixivium, and precipitating by an acid.
  - *Hepar antimonii.* By deflagrating crude antimony with nitre.
  - *Crocus metallorum.* Is hepar antimonii pulverifed and edulcorated with water.
  - *Diaphoretic antimony.* By deflagrating regulus of antimony with nitre.
  - *Antimoniated nitre.* By diffolving diaphoretic antimony in water, and allowing it to cryftallize.
  - *Magiftery of antimony.* By precipitating a folution of diaphoretic antimony by adding vinegar.
  - *Regulus antimonii medicinalis.* By fufing crude antimony with alkali. This is not properly a compound of alkali and antimony, but of another kind. But as it is a term much ufed, it was proper to explain it.
- Arsenic*. A metallic arfenical falt. By a particular elective attraction from regulus of antimony and nitre.

OILS.

- Expressed. *Soap.* The beft hard foap is made of olive-oil and foffile alkali. The ordinary white foap of this country is made of tallow and potafh; black foap with whale-oil and potafh.
- Essential. *Saponaceous mafs.* Beft made by pouring fpirit of wine upon cauftic alkali and then oil, digefting and fhaking.
- Empyreumatic. This mixture diffolves gold when precipitated from aqua regia; and is the bafis of the fine colour called *Pruffian blue;* and has various other properties, as yet but little known.
- Fossile. This has no name, nor are the properties well known; but from fome obfervations that have been made on native foapy waters, it is probable that it would keep linen much longer white than any other kind of foap.

SULPHUR.

- *Hepar fulphuris.* By injecting alkalies upon melted fulphur.
- *Lac fulphuris.* By diffolving fulphur in an alkaline lixivium, and precipitating by an acid.

WATER. *Alkaline lixivium,* when cauftic, or even the ordinary folution of mild alkali, is a fluid of great power in wafhing, bleaching, &c.

AIR. Fixed. *Mild alkali.* This is the general ftate in which alkalies are found; but if they are rendered cauftic by means of quick-lime or otherwife, they again abforb it from the air, or from many other bodies, by elective attraction. When perfectly mild, this alkali may be made to affume a cryftalline form.

The VOLATILE ALKALI, or SPIRIT of SAL AMMONIAC, can be united with thefe Bodies, viz.

ACIDS: Vitriolic, Nitrous, Muriatic, Vegetable; of Urine, of Amber, of Ants, &c.

ALKALI, as above.

METALS.

- Gold*.
  - *Aurum fulminans.* A powder obtained by precipitating it from aqua regia by volatile alkalies.
  - A liquid folution. By adding a large proportion of alkali after it has been precipitated from aqua regia. This depofites the gold when long expofed to the air. The curious vegetation called *arbor Dianæ* is formed by adding mercury to this folution. A violently fulminating powder obtained by digeftion.
- Silver*. A folution. After it has been precipitated from the nitrous acid. A fulminating powder by digeftion.
- Platina*. By folution, after having precipitated it from aqua regia.
- Copper.
  - A blue-coloured folution. By the ordinary means. This when evaporated to drynefs, and mixed with tallow, tinges the flame green.
  - Sapphire-coloured cryftals. By cryftallizing the folution.
  - *Venus fulminans.* By evaporating the folution to drynefs.
  - *Aqua cerulea fapphirina.* By mixing fal ammoniac, quick-lime, and thin plates of copper, with water, and allowing them to remain a night.
- Iron. By ordinary folution.
- Lead. By ditto.
- Tin. The mixts that are produced by thefe metals are little known.

SEMIMETALS.

- Bismuth*. By folution, after having precipitated it from the nitrous acid.
- Antimony.
- Cobalt. A reddifh liquor. By folution.
- Nickel. A blue liquor. By ditto.

OILS.

- Expressed. Has no name. By folution.
- Essential. *Sal volatile oleofum.* By ditto with fome difficulty, unlefs the alkali is in a cauftic ftate.
- Empyreumatic. A pungent oily fubftance, of great power in medicine. The principal one of this kind in ufe is fpirit of hartfhorn.
- Fossile. A particular kind of foapy fubftance.

SULPHUR. Smoking ſpirit of ſulphur. By diſtilling ſal ammoniac, quick-lime, and ſulphur.
ALCOHOL*. By diſtilling alcohol from volatile alkalies, it acquires a cauſtic fiery taſte; but the union is not complete.
WATER. This ſolution might be of uſe in waſhing or bleaching; but, unleſs in particular caſes, would be too expenſive. It coagulates with alcohol.
AIR. FIXED Mild volatile alkali. The uſual ſtate in which it is found; nor has any method yet been diſcovered of rendering it ſolid but in this ſtate.

EXPRESSED OILS may be combined with the following Subſtances, viz.

ACIDS: Vitriolic, Nitrous, Muriatic, Vegetable, of Urine, of Amber, as in the foregoing part of this Table.
ALKALIES: Fixed and Volatile, as above.
CALCAREOUS EARTHS. A kind of plaſter. By mixture when in a cauſtic ſtate.
METALS. { TIN*. Ditto. By ſolution when the tin is in the ſtate of a calx. LEAD*. Ditto. By boiling the calx of lead in oils. This is uſed for cements in water-works. The common white paint is a mixture of this leſs perfect. }
SEMIMETALS. ZINC*. Ditto. By ditto.
OILS: Eſſential, Empyreumatic, and Foſſile. By mixture but their uſes are not much known.
SULPHUR, *Balſam of Sulphur*. By ſolution in a boiling heat.
ALCOHOL. After expreſſed oils are freed from ſoap or plaſters, they are ſoluble in alcohol; but not in their ordinary ſtate.

ESSENTIAL OILS may be combined with the following Subſtances, viz.

ACIDS: Vitriolic, Nitrous, &c. as above.
ALKALIES: Fixed and Volatile, as above.
METALS. { COPPER. By ſolution. LEAD. By ditto. }
OILS of all kinds. By ſolution or mixture.
SULPHUR. A balſam of ſulphur. By ſolution, imperfectly; better by adding eſſential oils to the ſolution made by expreſſed oils or hepar ſulphuris.
ALCOHOL. { Imperfect mixture. By ſolution. Aromatic waters. By diſtillation. }
WATER. Diſtilled water of the ſhops. By diſtilling recent vegetable ſubſtances with water.

EMPYREUMATIC OILS may be combined with the following Subſtances, viz.

ACIDS: Vitriolic and Nitrous, as above.
ALKALIES: Fixed and Volatile, as above.
OILS of all kinds. By mixture.
ALCOHOL. By ſolution. By repeated diſtillations the oils are rendered much more ſubtile.

FOSSILE OILS may be combined with the following Subſtances, viz.

ACIDS: Vitriolic and Nitrous, as above.
ALKALIES: Fixed and Volatile, as above.
OILS of all kinds. By mixture.
SULPHUR. With ſome difficulty, by ſolution.
ALCOHOL. - - - By ditto.

SULPHUR may be combined with the following Subſtances, viz.

ACID*: Vitriolic; with the phenomena above deſcribed.
ALKALIES: Fixed and Volatile, as above.

METALS. {
SILVER. A maſs of red-like colour. By adding ſulphur to red-hot ſilver, and fuſing; found alſo with it in the ſtate of an ore.
LEAD. A ſparkling friable maſs, hardly fuſible. By deflagrating ſulphur with lead. This in a native ſtate forms the ore of lead called *galena*.
COPPER. A Black brittle maſs, eaſily fuſed. By adding ſulphur to red-hot copper, or ſtratifying with ſulphur and fuſing. Naturally in ſome yellow pyrites.
IRON. {
A ſpungy-like droſs, eaſily fuſible. By putting ſulphur to red-hot iron. This is alſo found naturally in the common yellow or brown pyrites.
A fulminating compound. By mixing filings of iron with ſulphur, moiſtening them with water, and preſſing them hard, they in a few hours burſt out into flame. This compoſition has been employed for imitating earthquakes.
Crocus martis. By deflagrating with iron.
Crocus martis aperiens. By calcining the crocus martis in the fire till it aſſumes a red appearance.
Crocus martis aſtringens. By puſhing the heat ſtill further. }
TIN. A dark-coloured maſs, reſembling antimony. By fuſion.
MERCURY. {
Ethiops mineral. By heating flowers of ſulphur, and pouring the mercury upon it, and ſtirring it well. Its natural ore is called *cinnabar*.
Factitious cinnabar. By applying the mercury and ſulphur to each other in their pure ſtate, and ſubliming.
Cinnabar of antimony. By ſubliming corroſive ſublimate and crude antimony; or the reſiduum, after diſtilling butter of antimony. } }

SEMIMETALS.

SEMIMETALS.
- BISMUTH. A faint greyish mass, resembling antimony. By fusion. If in its metalline state, the sulphur separates in the cold; but not so if the calx has been employed.
- ANTIMONY. *Crude antimony.* By fusion.
- ZINC*. A very brittle, dark-coloured, shining substance. With some difficulty, by keeping it long in a moderate fire, and covering it several times with sulphur, and keeping it constantly stirred.
- ARSENIC.
  - *Yellow arsenic.* By fusing it with $\frac{1}{10}$th its weight of sulphur.
  - *Red arsenic.* By ditto with $\frac{1}{5}$th its weight of sulphur.
  - *Ruby of sulphur*, or arsenic, or golden sulphur. By subliming when the proportions are equal.
  - *Orpiment.* A natural production; not perfectly imitable by art; composed of sulphur and arsenic. Much used as a yellow paint.
- NICKEL. A compound; compact and hard as lead; of a bright metallic appearance; internally yellow. By fusion.

OILS: Expressed, Essential, and Fossile, as above.

WATER. *Gas sylvestre.* By receiving the fumes of burning sulphur in water. This ought rather to be called a union of the volatile vitriolic acid with water.

ALCOHOL may be combined with the following Substances, viz.

ACIDS: Vitriolic, Nitrous, Muriatic, Vegetable, and of Borax, as above.

ALKALI*: Volatile, as above.

METALLIC calces, in some particular cases.

OILS: Expressed, Essential, Empyreumatic, and Fossile, as above.

WATER. By solution.

GOLD may be combined with the following Substances, viz.

ACIDS: Vitriolic*, Nitrous*, and Muriatic*. In the circumstances and with the phenomena above described.

ALKALIES: Fixed*, and Volatile*, as above.

METALS.
- SILVER. By fusion. And the same is to be understood of all the combinations of metals, unless particularly specified.
- PLATINA. Ductile, and of a dusky colour. This has been employed to debase gold, as it is of the same specific gravity, and is not discoverable by the usual tests for discovering the purity of gold.
- LEAD. A very brittle mass. Gold is rendered pale by the least admixture with this.
- TIN. A brittle mass when the tin is added in considerable quantity; but the former accounts of this have been exaggerated.
- COPPER. Paler and harder than pure gold. This mixture is used in all our coins, the copper being called the *alloy*.
- IRON. Silver-coloured, hard and brittle; very easily fused.
- MERCURY. Soft like a paste called an *amalgamum*. By solution; it being in this case called *amalgamation*; and the same is to be understood of the solution of any other metal in quicksilver.

SEMIMETALS.
- ZINC. A bright and whitish compound, admitting of a fine polish, and not subject to tarnish; for which qualities it has been proposed as proper for analysing specula for telescopes.
- ARSENIC. Brittle; and the gold is thus rendered a little volatile.
- ANTIMONY. A fine powder for staining glass of a red colour. By calcination.
- BISMUTH*. A brittle whitish regulus; volatile in the fire.
- COBALT.
- NICKEL. White and brittle.

SILVER may be combined with the following Substances, viz.

ACIDS: Vitriolic*, Nitrous*, Muriatic*, Vegetable*, and Acid of Ants*, as above.

ALKALIES: Fixed* and Volatile*, as above.

CRYSTALLINE EARTHS and other vitreous matters. A fine yellow opake glass. The finest yellow paint for porcelain is procured from glass mixed with silver.

METALS.
- GOLD, as above.
- PLATINA. Pretty pure and malleable. Difficult of fusion; and in part separates when cold.
- LEAD. Very brittle.
- TIN. Extremely brittle, as much so as glass.
- COPPER. Harder than silver alone. Used in small proportions as alloy in coins.
- IRON. A hard whitish compound.
- MERCURY*. By amalgamation with silver-leaf, or calx of silver precipitated by copper, but not by salts. This is used for silverizing on other metals, in the same way as the amalgamum of gold.

SEMIMETALS.
- ZINC. Hard, somewhat malleable, and of a white colour.
- ANTIMONY. A brittle mass.
- BISMUTH. A white semi-malleable body.
- ARSENIC. Brittle; the silver being rendered in part volatile.
- COBALT.

SULPHUR, as above.

LEAD may be combined with the following Substances, viz.

ACIDS: Vitriolic, Nitrous, Muriatic, Vegetable, of Urine, of Ants, as above.

ALKALIES: Fixed and Volatile, as above.

CRYSTALLINE EARTHS. A thin glafs. By fufion in a moderate heat.

METALS.
- GOLD and Silver, as above.
- PLATINA. Of a leafy or fibrous texture, and purplifh or blue colour when expofed to the air. If a large proportion of platina is ufed, it feparates in the cold.
- TIN. A little harder than either of the metals, and eafily fufed: hence it is ufed as a folder for lead; and it forms the principal ingredients of pewter. If the fire is long continued, the tin floats on the furface.
- Copper*. Brittle and granulated, like tempered iron or fteel when broke. By throwing pieces of copper into melted lead. The union here is very flight.
- IRON*. An opaque brownifh glafs. By a great degree of heat if the iron has been previoufly reduced to the ftate of a calx; but never in its metallic ftate.
- MERCURY*. By amalgamation. Effected only in a melting heat, unlefs fome bifmuth has been previoufly united with the mercury.

SEMIMETALS.
- ZINC. Hard and brittle. By pouring zinc on melted lead. If the zinc is firft melted, and the lead injected upon it, it then deflagrates.
- ANTIMONY*.
- BISMUTH. A grey-coloured femi-malleable body, eafily fufed; and thence ufed as a folder for lead or tin.
- ARSENIC.
  - A grey-coloured brittle mafs, eafily fufed, and extremely volatile.
  - A hyacinth-coloured glafs. By fufion in a confiderable heat. This glafs is eafily fufed; and is a much more powerful flux than pure glafs of lead.
- COBALT. The nature of this compouud is not known.
- NICKEL. A brittle metallic body.

OILS: Expreffed* and Effential, as above.

SULPHUR, as above.

TIN may be combined with the following Subftances, viz.

ACIDS: Vitriolic*, Nitrous*, Muriatic, Vegetable*, of Urine, as above.

ALKALIES: Fixed and Volatile, as above.

CRYSTALLINE EARTHS or other vitreous matters. An opaque white vitreous mafs, which forms the bafis of white enamels.

METALS.
- GOLD, Silver, and Lead, as above.
- PLATINA. A coarfe hard metal which tarnifhes in the air.
- COPPER. A brittle mafs. When the copper is in fmall proportions, it is firmer and harder than pure tin. This, in right proportions with a little zinc, forms bell-metal.
- IRON. A white brittle compound. By heating filings of iron red-hot, and pouring melted tin upon them. A metal refembling the fineft filver is made of iron, tin, and a certain proportion of arfenic.
- MERCURY. This amalgamum forms foils for mirrors; and forms the yellow pigment called *aurum mofaicum*. By being fublimed with fulphur and fal ammoniac.

SEMIMETALS.
- ZINC. Hard and brittle. When the zinc is in fmall proportions, it forms a very fine kind of pewter.
- ANTIMONY* *Regulus veneris*. By elective attraction from copper and crude antimony.
- BISMUTH. Bright, hard, and fonorous, when a fmall proportion of bifmuth is ufed. This is very eafily fufed, and employed as a folder.
- ARSENIC. A fubftance in external appearance refembling zinc.
- COBALT. By fufion.
- NICKEL. A brittle metallic mafs.

OIL: Expreffed*, as above.

SULPHUR, as above.

COPPER may be combined with the following Subftances, viz.

ACIDS: Vitriolic, Nitrous, Muriatic, Vegetable, of Urine, of Amber, of Ants, as above.

ALKALIES: Fixed, and Volatile, as above.

METALS.
- GOLD, Silver, Lead*, and Tin, as above.
- PLATINA. A white and hard compound, which does not tarnifh fo foon as pure copper, and admits of a fine polifh.
- IRON. Harder and paler than copper. Eafily fufed.
- MERCURY*. A curious amalgam. Soft at firft, but afterwards brittle. By triturating mercury with verdigris, common falt, vinegar, and water.

SEMIMETALS.
- ZINC.
  - *Brafs*. Commonly made by cementation with calamine. The larger the proportion of zinc, the paler, harder, and more brittle is the brafs.
  - *Prince's metal, pinchbeck*, and other metals refembling gold. By employing zinc in fubftance in fmall proportions. The beft pinchbeck about 1-4th of zinc.
  - *Spelter*. A native fubftance, found in Cornwall, confifting of zinc and copper, and ufed as a folder.
- ANTIMONY. By fufion.
- BISMUTH. A palifh brittle mafs. Somewhat refembling filver.
- ARSENIC. *White copper*. By pouring arfenic, fufed with nitre, upon copper in fufion. If too large a proportion of arfenic is ufed, it makes the compound black and apt to tarnifh.
- COBALT. White and brittle.
- NICKEL. White and brittle, and apt to tarnifh.

OILS: Effential, as above.

SULPHUR, as above.

IRON may be combined with the following Subſtances, viz.

ACIDS: Vitriolic, Nitrous, Muriatic, Vegetable, of Urine, of Amber, of Ants, as above.
ALKALIES: Fixed*, and Volatile, as above.
VITRESCENT EARTHS. A tranſparent glaſs. In general blackiſh; but ſometimes yellow, green, or blue. The colour is influenced by the degree of heat as well as nature of the ingredients.

METALS.
- Gold, Silver*, Lead*, Tin, and Copper, as above.
- Platina. With caſt iron it forms a compound remarkably hard, ſomewhat ductile, and ſuſceptible of a fine poliſh.

SEMIMETALS.
- Zinc. A white ſubſtance reſembling ſilver.
- Antimony. The magnetic quality of the iron is totally deſtroyed in this compound.
- Bismuth. In a ſtrong heat, this emitteth flames.
- Arsenic. A whitiſh, hard, and brittle compound. By fuſing with ſoap or tartar. A metal reſembling fine ſteel is made by fuſing caſt iron with a little arſenic and glaſs.
- Cobalt. A compound remarkably ductile. By fuſion in a moderate heat.
- Nickel. A brittle maſs.

SULPHUR, as above.

MERCURY may be combined with the following Subſtances, viz.

ACIDS: Vitriolic, Nitrious, Muriatic, Vegetable*, of Urine, as above.
ALKALI: Fixed*, as above.

METALS.
- Gold, Silver*, Lead*, Tin, and Copper, as above.
- Platina. The compound reſulting from this mixture is not known.

SEMIMETALS.
- Zinc. An amalgam. Soft or hard, according to the proportions employed.
- Antimony. By melting the regulus, and pouring it upon boiling mercury. By frequently diſtilling from this amalgam, the mercury is rendered much more pure, and then is called *animated mercury*.
- Bismuth. A ſilverizing for iron. By putting this amalgam upon iron, and evaporating the mercury. It has much the appearance of ſilver.
- Cobalt. By mixing firſt with nickel, and then adding mercury.

SULPHUR, as above.

ZINC may be combined with the following Subſtances, viz.

ACIDS: Vitriolic, Nitrous, Muriatic, Vegetable, of Urine, of Amber, of Ants, as above.

METALS.
- Gold, Silver, Lead, Tin, Copper, and Iron, as above.
- Platina A hard ſubſtance.
- Mercury, as above.

SEMIMETALS.
- Antimony. This mixture is applied to no particular uſe.
- Arsenic. A black and friable maſs.
- Cobalt. The particular nature and properties of this mixt is not known.

OIL: Expreſſed*, as above.
SULPHUR*, as above.

ANTIMONY may be combined with the following Subſtances, viz.

ACIDS: Vitriolic*, Nitrous, Vegetable*, and Urinous. With the phenomena, and by the means above deſcribed.
ALKALIES: Fixed and Volatile, as above.
VITREOUS EARTHS. A thin penetrating glaſs; which is a powerful flux of metals.

METALS.
- Gold, Silver, Lead, Tin*, Copper, and Iron, as above.
- Ptatina. A hard maſs.
- Mercury, and Zinc, as above.

SEMIMETALS.
- Bismuth. A maſs reſembling regulus of Antimony.
- Arsenic. The nature and qualities of this mixt are not known.
- Cobalt. Nature unknown.
- Nickel. Ditto.

SULPHUR, as above.

BISMUTH may be combined with the following Subſtances, viz.

ACIDS: Vitriolic, Nitrous, Muriatic, Vegetable, and Urinous; with the phenomena, *&c.* above deſcribed.
ALKALIES: Fixed*, and Volatile*, as above.
VITREOUS MATTERS. A yellow glaſs. The ore of Biſmuth affords with theſe a blue glaſs; but this is probably owing to ſome mixture of Cobalt with it.

METALS.
- Gold, Silver, Lead, Tin, Copper, and Iron, as above.
- Platina. This mixture changes its colour much on being expoſed to the air.
- Mercury, as above.

SEMIMETALS.
- Antimony, as above.
- Arsenic. Nature not known
- Cobalt*. By mixing firſt with with nickel or regulus of antimony, and then adding cobalt; but it cannot be united by itſelf.
- Nickel. This mixt is not known.

SULPHUR, as above.

ARSENIC may be combined with the following Subſtances, viz.

ACIDS: Vitriolic, Muriatic*, Vegetable*, and Urinous; with the phenomena, *&c.* abovementioned.

ALKALIES.

ALKALIES : Fixed, and Volatile ; with the phenomena, and by the means mentioned above.
VITREOUS MATTERS. A glafs which greatly promotes the fufion of other fubftances. The arfenic muft firft be prepared by diffolving and precipitating from alkalies.
METALS. { GOLD, Silver, Lead, Tin, Copper, and Iron, as above. / PLATINA.
SEMIMETALS. { ZINC, Antimony, and Bifmuth, as above. / COBALT. / NICKEL. The phenomena attending thefe mixtures have not been as yet particularly obferved.
SULPHUR, as above.

PLATINA may be combined with the following Subftances, viz.

ACIDS : Muriatic*; with the phenomena, *&c.* mentioned above.
ALKALI : Volatile, as above.
METALS : GOLD, Silver, Mercury, Tin, Copper, and Iron, as above.
SEMIMETALS. { ZINC, Bifmuth, and Arfenic, as above. / COBALT. / NICKEL. The phenomena attending thefe mixtures not yet obferved.

COBALT may be combined with the following Subftances, viz.

ACIDS : Vitriolic, Nitrous, Muriatic, and Urinous ; with the phenomena, *&c.* as above defcribed.
ALKALI : Volatile, as above.
EARTHS. CALX of FLINT. { *Saffre.* By mixing calcined cobalt with calx of flint, and moiftening them with water, and preffing them clofe in wooden tubs. / *Smalt.* By vitrifying thefe with the addition of a little potafh.
METALS : GOLD, Silver, Platina, Mercury*, Lead, Tin, Copper, and Iron, as above.
SEMIMETALS. { ZINC, Antimony, Bifmuth*, and Arfenic, as above. / NICKEL. The properties of this compound not known.

NICKEL may be combined with the following Subftances, viz.

ACIDS: Nitrous, and Muriatic ; with the phenomena, *&c.* as mentioned above.
ALKALI : Volatile, as above.
METALS : Gold, Platina, Lead, Tin, Copper, and Iron, as above.
SEMIMETALS : Antimony, Bifmuth, Arfenic, and Cobalt, as above.
SULPHUR, as above.

ABSORBENT EARTHS may be combined with the following Subftances, viz.

ACIDS : Vitriolic, Nitrous, Muriatic, and Vegetable ; with the phenomena, and by the affiftances abovementioned.
ALKALIES: Fixed as above.
EARTHS. { CRYSTALINE. By this mixture they are both much eafier melted into glafs than by themfelves, but not without the addition of fome alkali. / ARGILLACEOUS. This mixture eafily runs into a glafs without any addition.
WATER. *Lime-water.* By folution. It is fometimes found flowing out of the earth in fprings ; and as it always quits the water when expofed to the air, it is there depofed on the banks of the ftreams, forming the ftony incruftations called *petrifications* : And filtering through the pores of the earth, and dropping through the roofs of fubterraneous caves, it forms the curious incruftations found hanging from the roof of fuch places ; fometimes affuming forms ftupenduoufly magnificent.
AIR. FIXT. *Lime-ftone.* It is from the quality that quick-lime has of abforbing its air, again with it refuming its ftony confiftence, that it is fitted for a cement in building ; and the great hardnefs of the cements in old buildings is owing to the air being more perfectly united with thefe than in newer works.

CRYSTALLINE or VITRESCENT EARTHS may be combined with the following Subftances, viz.

ACIDS : Vitriolic*, and Nitrous*; with the phenomena, *&c.* as abovementioned.
ALKALI : Fixed, as above.
ABSORBENT EARTHS : as above.
ARGILLACEOUS EARTHS. A mafs running into glafs in a moderate heat.
METALS : Lead, Tin, Copper, and Iron, as above.
WATER. Although this is not foluble in water by any operation that we are acquainted with ; yet, from its cryftalline form, it is probable that it has been once fufpended ; and certainly it is fo at this day in thofe petrifying fprings whofe incruftations are of the cryftalline fort.
SEMIMETALS : Antimony, Bifmuth, Arfenic, and Cobalt, as above.

ARGILLACEOUS EARTH may be combined with Abforbent and Cryftalline Earths, as above. With water it only unites into a pafte of a mechanical nature.

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Bergman's

Argonauts,

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Dobson, Thomas, *A system of chemistry*…, WZ 270 S995c 1791
Condition when received: The cloth-cased book was in poor condition. The glued spine was cracking, sewing was breaking and some pages were detaching. Black mold was present along the gutter on pages 80-90. Bookplate on inside front cover was lifting. Foldout: An oversized foldout opposite page 230 was detached from the book. It was acidic and folds were weak. In addition, there were several large tears in the foldout that had been mended using scotch tape.
Conservation treatment: The book was surface cleaned using a Hepa vacuum with micro tools. Mold was deactivated (269 pages) using a spray-applied mixture of 20% deionized water with 80% ethyl alcohol (Nasco). The text block was brought into plane using mild pressure. The tape carrier had lost adhesion with age and popped off without resistance. The foldout was submerged in a solution of 1:1 methylene chloride and toluene (Fischer Scientific). As a result, the adhesive was significantly reduced. The pages were submerged in a series of baths using deionized water conditioned to pH 8.5 using a combination of ammonium hydroxide (Nasco) and calcium hydroxide (Nasco). The paper was allowed to dry thoroughly between each of three baths. The third bath was conditioned using only calcium hydroxide. As a result, a minute amount of alkaline reserve (calcium carbonate) was amalgamated and precipitated in the paper. After washing, the paper was lighter in color, stronger, and the acidic content was lower. Foldout tears were mended using tosa tengujo and kizukishi (all papers from Japanese Paper Place) and secured with zin shofu wheat starch paste (BookMakers). Foldout was repositioned opposite page 230 and hinges into gutter using sekishu paper (above). Hinge and bookplate was adhered using the above adhesive.
Conservation carried out by Rachel-Ray Cleveland
NLM Paper Conservator, 01/2007