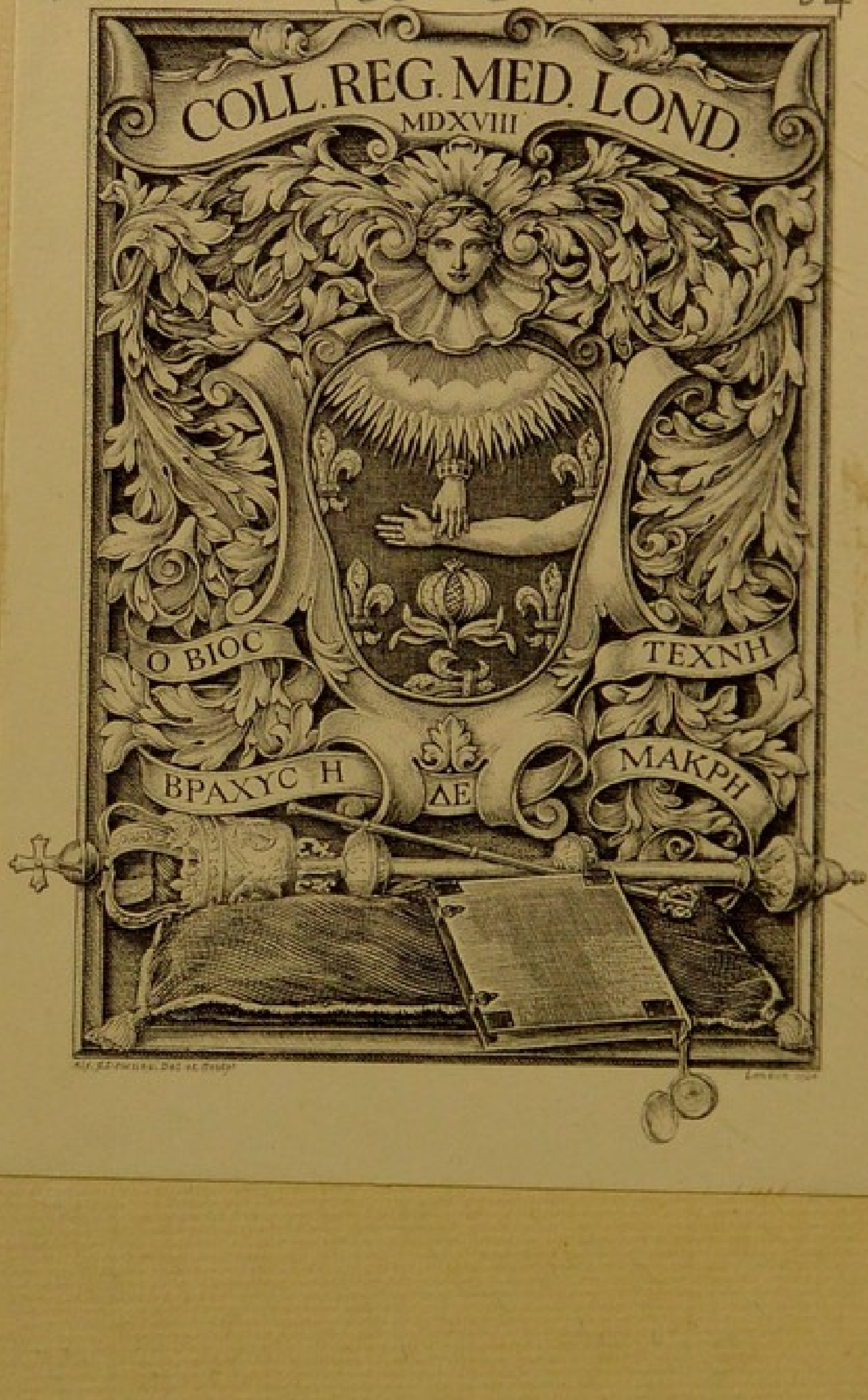
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THE

FIRST PRINCIPLES

OF

CHEMISTRY.

THE

FIRST PRINCIPLES

OF

CHEMISTRY.

BY

WILLIAM NICHOLSON.

THE SECOND EDITION, WITH IMPROVEMENTS.

LONDON:

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M.DCC.XCII.

PREFACE.

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

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

I believe I fcarcely need remind the man of fcience, that the great number of labourers in the chemical examination of bodies, has rendered it a difficult tafk to collect the various facts, which lie diftributed in the acts of academies, and a variety of literary journals. It is not very eafy to procure thefe books: and the perufal of them produces a voluminous table of references; in which fome things may be overlooked, even when noted. A certain degree of imperfection muft arife, in every general treatife, from this caufe. I have endeavoured to diminifh it as much as poffible.

In treating of facts long fince eftablifhed, and fuch whofe difcoverers are unknown to me, I have not quoted my authors; for, though I would gladly do juftice to all claims, yet the inveftigation of chemical hiftory is foreign to the object of my prefent purfuit. Whenever I have quoted, it is to be underftood that the authors are worthy of credit and refpect; and that the reader will, in almoft every inftance, find his advantage in confulting them for a fuller account of the fubject. But I have quoted thefe only when it appeared neceffary either to complete the information intended to be conveyed, or to clear myfelf from feeming to lay claim to their difcoveries.

With regard to nomenclature and theory, I have attempted to keep clear of every fyftem. I have called things by fuch names as are moft in ufe, except where the ufual name pointed too evi-

dently

dently at theories either long ſince exploded, or not yet proved: and in the relation of facts I have found it much leſs difficult to exclude theoretical alluſions than I at firſt apprehended, when I formed the determination of confining the theory, for the moſt part, to the ends of chapters. It would be very advantageous to ſcience if this reſolution, which I have adhered to with my beſt endeavours, were more generally adopted. I do not, however, wiſh to be thought blind to the advantages of an uniform nomenclature, or a conſiſtent theory; but muſt urge my conviction that the former ought to be founded on the moſt incontrovertible facts only, becauſe the nomenclature of any mere theory may be productive of worſe conſequences than the moſt confuſed ſet of terms can poſſibly occaſion. The ſyſtemizing of words, inſtead of things, is the fruitful ſource of paralogiſm; and it is by falſe reaſoning of this kind that a well-methodized hypotheſis may be ſupported, long after the pretended facts are overthrown upon which it was originally built. Upon the two theories of chemiſtry I have ſpoken like one who admits neither in any other way than as probable ſuppoſitions, which have not yet been experimentally eſtabliſhed. The logic of the managers of the controverſy for and againſt phlogiſton, appears to me to be exceedingly defective in a great number of inſtances. The exiſtence of this chemical element is indeed very far from being well aſcertained; but, on the other hand, there are many

many difficulties which attend the confideration of chemical facts without it. As I think the anti-phlogiftic hypothefis equally probable with the modified fyftem of Stahl, and more efpecially as the excellent works of a number of French chemifts are written in the language of that hypothefis, I have judged it proper to explain both. And this I have endeavoured to do in fuch a way, as to create in the chemical ftudent an habit of fteadily and calmly attending to the operations of nature; inftead of indulging that hafty difpofition for theorizing, which indeed might pafs, on account of its evident impropriety, without any earneft cenfure, if we had not the mortification to fee it too much practifed by men entitled to the beft thanks of the fcientific world, and on that account poffeffing greater power to miflead.

London,
Jan. 25, 1790.

I HAVE carefully revifed the fecond Edition of this Work: the new difcoveries are inferted; and no exertions have been fpared to render it worthy of the diftinguifhed approbation it has met with.

London,
Nov. 10, 1791.

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n i EMENDA-

EMENDATIONS AND ADDITIONS.

I HAVE not obferved any error of the Prefs but fuch as the fenfe of the context will obvioufly tend to rectify.

In the Chapter on Nitrous Acid I have omitted to infert an account of the very important difcovery of the Rev. Ifaac Miner, B.D. F.R.S. inferted in the LXXIXth vol. of the Philofophical Tranfactions. This gentleman, finding, as well from his own experiments as thofe of others, that volatile alkali is afforded in various inftances of the application of nitrous acid to metals (fee page 336 of the following treatife), was almoft immediately ftruck with the notion, that the procefs might be inverted. That is to fay, as the phlogifticated air of nitrous acid, when made to combine with inflammable air, affords volatile alkali; fo, on the contrary, if vital air could, by any effect of the chemical affinities, be made to engage with the phlogicated air of volatile alkali, while the other principle, namely, the inflammable air, fhould be either retained or difengaged, the refult of fuch an engagement or combination would be the nitrous acid in fome of its modifications. For this purpofe, he crammed a gun-barrel full of manganefe in coarfe powder, which fubftance is known to afford vital air by heat, and to one end of this tube he applied a retort containing the cauftic volatile alkali. Heat was then applied to the gun-barrel, and, as foon as it was ignited, he placed a candle beneath the retort, which caufed the volatile alkali to boil, and pafs through the gun-barrel in the form of alkaline air: the confequence was, that nitrous air was emitted at the other end of the tube.

He likewife repeated the experiment with fuccefs; ufing martial vitriol calcined to whitenefs, inftead of manganefe. The whole paper is highly deferving the attention of chemifts.

 In

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

In the fourth Chapter of the first Book of this Work, I had observed in a note, that very complete sets of small apparatus for experiments with the blow-pipe, and with small retorts and receivers, were sold in London, under the inspection of Mr. Magellan, by Messrs. Jones, [illegible], [illegible] &c. in the Strand. The death of that worthy and active philosophic [illegible] has occasioned our [illegible] in the present edition; but Mr. [illegible] has since acquainted me that he has a considerable number of [illegible], I think I shall render a service to [illegible] by [illegible]ing the latter [illegible] in this place.

BOOK I.

GENERAL CHEMISTRY.

CHAP. I.

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

GENERAL OBSERVAT.

Chemiſtry defined.

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

Analyſis.

Syntheſis.

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

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

GENERAL OBSERVAT.

Heat.

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

Analyſis by heat.

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

Attraction.

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

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

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

Chemical attractions

—act by means of heat

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

Art of the chemift.

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

Elective attractions.

GENERAL OBSERVAT.

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

Dry and humid way.

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

Terms of art.

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

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CHAP. II.

ON HEAT.

HEAT. Of the word heat.

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

Word heat.

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

Temperature.

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

Cauſe of temperature.

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

Common temperature.

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

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

Conductors of heat.

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

Solid, fluid, and vaporous ſtates.

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

HEAT.

Expansion by heat.

parates water from salts, by causing the former to fly off in vapour. Lastly, if neither the change of temperature be considerable enough to alter the state of solidity, fluidity, or vapour, which the body under consideration may happen to possess; nor the body itself be of that nature as to undergo a separation of its parts by the change; then an increase of temperature will cause an increase in the bulk or dimensions of the body, which will last no longer than during the time of the increase.

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

It has already been observed, that the temperature at which different bodies change their form, is various. Neither this property, nor the expansions of bodies by heat, have been observed to have any correspondence with their density, hardness, specific gravity, or other evident properties. There are likewise some irregularities in the contraction or expansion, which depend on circumstances not yet well ascertained, near the freezing point of water, and probably other substances. Pure water, when cooled, is observed to contract till within about 8 degrees of the freezing temperature, where it begins to expand; and it may be cooled 11° below that temperature, and still continue fluid. An adequate explanation of the circumstances that attend the conversion of bodies from their several states, of solidity, fluidity, and vapour, seems to promise a more intimate acquaintance with the nature and properties of the particles of bodies than has hitherto been obtained.

Irregularities.

Elastic fluids.

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

are

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

Quantity of heat in equal bodies:

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

—differing in temperature

If two fuch equal and fimilar bodies, that differ in temperature, be brought together, they will by communication acquire a common temperature, and their quantities of heat will by that means be rendered equal. For this purpofe it is clear that the hotter of the two bodies muft have communicated half its excefs to the colder: the quantity of heat in one of thefe two equal bodies will therefore be an arithmetical mean between the two quantities originally poffeffed by each of them; that is to fay, its temperature, or the common temperature, will exceed that of the colder exactly as much as it falls fhort of that of the hotter body.

— in unequal bodies.

If the two bodies had been unequal, they would neverthelefs have acquired a common temperatnre by communication, but the excefs of heat would not have

been

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

Quantities of heat required to change temperature.

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

Thermometer;

The foregoing deductions naturally lead us to the conſideration of an inſtrument proper to ſhew the temperatures of bodies. Such an inſtrument will require to be placed in contact with the body under examination, in order that it may acquire the ſame

—its requiſites.

temperature. It is therefore an indiſpenſable condition, that the inſtrument ſhould be of that ſmall bulk as not ſenſibly to heat or cool the body it touches; but that the common temperature of the inſtrument, and the body itſelf upon contact, may, without perceptible error, be taken for the original temperature of the body.

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

Mercurial thermometer.

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

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

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

—By Crawford.

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or to receive heat, were the fame in water at all temperatures; becaufe it is clear that, if this difpofition be changed by heating or cooling, the temperature, or power to heat or cool other bodies, will not follow the fame proportion as the quantities of heat; though it may be imagined, not without probability in this cafe, that correfpondent irregularities in the expanfions of the mercury, may caufe the thermometer to indicate the arithmetical mean between the two expanfions produced by any extreme temperatures. But whatever irregularities may be fuppofed to counteract each other in thefe experiments with mercury and water, it is to the laft degree improbable that the fame compenfation would be found, when the mean temperature is obtained by other methods. With this view the celebrated Dr. Crawford * very carefully repeated and confirmed Mr. De Luc's experiments; made others with a like refult, by ufing linfeed oil inftead of water, and alfo by producing the mean temperature, permanently, in air included in a cylinder formed of two equal parts, the upper of which was kept to the freezing point, by furrounding it with pounded ice; and the lower to the boiling-water point, by furrounding it with a greater fupply of fteam than could be condenfed by its contact. The near correfpondence of thefe feveral methods fhews that the expanfions of the mercury in the thermometer are correfpondent with the heat it receives.

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

Thus

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

Quantities of heat in bodies of different kinds: —relative.

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

—abfolute.

To illuftrate this by an example in round numbers:

Example.

Suppofe

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Suppofe a pint of mercury, at the temperature of 136°, be mixed with a pint of water at 50°, the mean temperature will be 76°. The water therefore has been heated 26°, and the mercury has been cooled 60°, by the lofs of the heat it imparted to the water. The abfolute heat in one degree of the mercury will confequently be proportionally lefs than that of one degree of the water; becaufe the very fame heat which has raifed the water 26 degrees in temperature, would raife the mercury fixty, if it could be returned again: and the whole heat contained in the mercury will be to that of the water in the fame proportion of 26 to 60. But in the prefent experiment equal bulks were ufed; and mercury is about 13 times as heavy as water. An equal weight of mercury would contain only one-thirteenth part of the heat. Twenty-fix, divided by 13, quotes 2: whence the comparative heats of mercury and water are in the proportion of about 2 to 60, or 1 to 30; that is to fay, a pound of mercury, at the fame temperature, contains no more than one-thirtieth part of the heat contained in a pound of water.

Comparative heat.

It may be obferved that the term comparative heat is ufed to denote the proportion of the abfolute quantity of heat in one body to that of another equal mafs of matter at the fame temperature, confidered as a ftandard. The ftandard made ufe of is pure water, in a fluid ftate. Some writers call this fpecific heat. The difpofition, or property, by which bodies feverally require more or lefs heat to produce equal changes in their temperature, is called their capacity for heat. Thefe capacities are confidered as the unknown caufe of the differences in their comparative heats, to which they are confequently proportional.

Capacity.

It

Capacities in various ſtates.

It is found, by experiment, that the capacity of the ſame body for heat is leaſt when ſolid, greater when fuſed or fluid, and greateſt of all when it becomes converted into vapour, or elaſtic fluid.

—changes by chemical actions.

Alſo, when bodies unite by virtue of chemical attraction, their capacities are ſeldom the ſame as the ſum of the capacities of the bodies, but almoſt always either greater or leſs.

Inferences.

As the experiments relating to the capacities of bodies cannot be here given at large, it will be proper to mention, by way of inference, ſome of the chief conſequences of this moſt luminous doctrine; firſt premiſing, however, that theſe inductions have all been verified by experiment*.

Ice and water.

The capacities of ice and fluid water are found to be as 9 to 10. Ice cannot therefore be converted into water, unleſs it be ſupplied with as much heat as is ſufficient to anſwer the difference of capacity. Thus, if equal quantities of ice and water, both at the temperature of 32°, or the freezing point, be expoſed in ſimilar veſſels, at the ſame diſtance from a fire, both will receive heat alike; and the ice will be melted into water at 32°, while the water in the other veſſel will have its temperature raiſed to 178°. Here it is obvious that the ſame heat which raiſed the water 146 degrees, was merely ſufficient to ſupply the increaſed capacity of the ice; for which reaſon this laſt had not its temperature raiſed at all. If the experiment be more accurately made, by mixing equal weights of water at 178°, and ice at 32°, the ſame conſequence will follow;

* For which conſult Dr. Crawford's Treatiſe, already ſpoken of.

for

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

Stationary temperature, or freezing point.

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

Natural zero of temperature.

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

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

Capacity of ſteam.

No direct experiment has yet been made to ſhew the capacity of ſteam with relation to water. An indirect experiment of Dr. Crawford makes it as $15\frac{1}{2}$ to 10 †. It is accordingly found that ſteam, in its condenſation into water, gives out as much heat as would raiſe an equal quantity of non-evaporable matter, of the ſame capacity as water, 914 degrees. This heat it muſt have taken up at its formation. Whenever water is heated, we may conſequently conſider the heat as diſpoſed of in two ways. One part raiſes the temperature of the fluid water, and the other part is employed in ſupplying the elaſtic vapour that flies off with the heat which its increaſed capacity requires at that temperature. The greater the quantity of ſteam is produced, the larger will be the proportion of the heat employed in this laſt way. Now, there is a difficulty attends the formation of elaſtic vapour, in proportion as its eſcape is rendered more difficult. If the water be heated in a cloſe veſſel, no ſteam will be formed; if the ſteam eſcape by a ſmall hole, there will be leſs formed than if the whole ſurface of the water were uncovered; and if the ſuperincumbent atmoſphere be removed, as in the vacuum of an air-pump, the production will be greateſt of all. As the heat of the

* Crawford, p. 458. † Ibid. page 270.

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water goes on increafing, the production of fteam will likewife increafe, until the quantity is fo great as its augmented capacity to carry off the whole heat that is communicated. At this period the increafe of temperature will therefore ceafe, and the temperature will become ftationary. This point is called the boiling-water point. It varies, however, a little, as the preffure of the atmofphere varies, being loweft when that is leaft; becaufe the maximum of fteam is produced at a lower temperature when the obftacle to its efcape is lefs. It has been ftated, and with fome probability, that there might be no interval of fluidity between the folid and vaporous forms, if it were not for the preffure of the atmofphere.

Boiling-water point of temperature.

Evaporation produces cold.

In this manner it is eafy to account for the cold produced by evaporation: for the volatile fubftance, when it takes the vaporous form, abforbs as much heat from the body from which it evaporated, as its increafed capacity requires. Every one muft be acquainted with the cold produced by wetting the hand with water or with fpirits of wine or brandy. The freezing of water, by means of the evaporation of ether, is a very remarkable inftance of this. Water is included in a thin glafs tube, and the outfide of the tube is kept continually wetted with ether, by means of a bottle with a capillary tube in its neck, through which the ether is poured. The confequence of the fpeedy evaporation of this very volatile fluid is, that in a very fhort time the included water is fuddenly converted into ice, even before a fire, or in the midft of fummer.

Freezing by evaporation.

Freezing mixtures.

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

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

Fixed temperature of freezing mixtures.

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

Freezing proceffes by diffolving falts in water.

* Crawford, p. 474.

† Walker, in Philof. Tranf. Vol. LXXVII. and LXXVIII.

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Mixture of falts for freezing water.

these may be here mentioned, not as the moſt powerful, but becauſe the materials are cheap, and well known. It conſiſts of equal parts of ſal-ammoniac and ſaltpetre, finely powdered. If four ounces of water be poured on three ounces of this mixture, the ſolution will ſink the thermometer 36 degrees; and as it is eaſy to have pump-water as cool as 50° in the midſt of ſummer, this addition will cool it to 14°, which is therefore ſufficient to freeze water in a phial plunged in it.

General view of the agency of heat.

Without entering more largely into examples of the conſequences of the change of capacity in bodies which are changed in their form, or ſtate of chemical combination, it may be obſerved, in general, that as the powers of gravity and projection, in continual oppoſition to each other, produce all the beautiful effects in the great ſyſtem of the univerſe to which they are eſſential; ſo, among the actions of the minute parts of bodies, the coheſive attraction, and the energy of heat, are in continual oppoſition to each other, and are concerned in every proceſs by which changes are produced in the peculiar properties of bodies: and for whatever more immediate purpoſes it may be that the Supreme Intelligence has thus generally appointed their agency, we ſee that the changes of capacities are greatly conducive to the preſervation of a more equal temperature than would otherwiſe be found in the diſtricts around us. The cold produced by evaporation greatly mitigates, and conducts to other parts, the ſtrong heats of the torrid zone; and the heat developed on the freezing of water prevents the cold from falling ſo far below the freezing point as otherwiſe it might do.

Advantages ariſing from the changes of capacities.

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do. If the capacities of water and ice were equal, the freezing of immenfe bodies of water would fcarcely be progreffive, but would take place the inftant the whole was cooled to 32°; and fo likewife the thawing of vaft tracts of fnow and mountains of ice would be performed in the fhort time of the tranfmiffion of the heat required to raife its temperature the minuteft portion of a degree above the temperature of folidity. Whether the extreme inconveniences the hotter climates would undergo from increafed heat, or the colder from the intenfe freezing and fudden thaws, be among the principal events in the view of the Sovereign Difpofer of the univerfe, cannot, from our ignorance of final caufes on fo large a fcale, be determined.

Queftion, page 6.

Whether heat be matter or motion, is a queftion which, as was before obferved, is not well fettled. It is certain that the motion of friction, or percuffion, either produces or collects heat; and if the fuppofition of the mere vibration of parts could adequately account for the effects, it would doubtlefs be more fimple than to call in the affiftance of a material fubftance endued with peculiar properties. But, on the other hand, the appearances are folved with great eafe and fimplicity by the fuppofition of fuch a fubftance. On this fubject it may perhaps be fufficient to obferve, that the phenomena of heat feem to ftand fingle, fo as not eafily to admit of comparifon with any of the other appearances in nature; and confequently that all reafoning by analogy promifes very little elucidation of a fubject which can only be profecuted by experimental refearch.

The philofophy of heat admits no analogy.

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Diminution of capacity increafes weight.

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

* Dr. George Fordyce made the experiment by weighing the fame quantity of water (about 1700 grains), when frozen and when unfrozen, at the temperature of 32°, in a room where the air was of the fame temperature. The ice was near one-fixteenth of a grain heavier. Phil. Tranf. Vol. LXXV. p. 362.—Sir Benjamin Thompfon obtained the fame conclufion, by counterpoifing water againft fpirit of wine, and expofing the apparatus to a cold atmofphere which froze the former.

CHAP.

CHAP. III.

THE CONSTRUCTION OF THE THERMOMETER.

THERMOMETER.

Construction of the thermometer.

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

To determine the cylindrical form of the bore.

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

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

Method of blowing thermometers.

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

Filling with mercury.

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

defend the finger and thumb from its heat. The mercury will foon boil, and moft of the remaining air will be heard efcaping from the bulb. As foon as this efcape has ceafed, remove the bulb from the candle, and it will be fuddenly filled with mercury from the veffel. THERMOMETER.

Take the thermometer thus filled out of the mercury, and wrap round its open end a piece of thin paper, in fuch a manner as to leave a cavity beyond the tube, at leaft fufficient to hold as much mercury as the bulb contains; fecure this by wrapping it tight with packthread about the tube; then put a drop of mercury into the paper cavity, and apply the bulb again over the fnuffed candle, holding the tube upright between the finger and thumb, or a pair of fmall pincers, at the part wrapped with paper and packthread: the mercury will foon boil, and about half the contents of the bulb will rufh violently up the tube into the paper. Remove the bulb from the candle, and the mercury will fuddenly return: then boil it again; and repeat the operation till the fpeedy boiling of the mercury, when placed over the candle, and the diminifhed noife and agitation, fhew that the whole has been well heated, and deprived of the air or moifture which might have adhered to it. Boiling the mercury in the tube.

The operation of boiling will fail, if the mercury, or the infide of the bulb, be moift; for in this cafe the bulb is ufually burft by the mercurial vapour; the explofion however is not dangerous: it is very likely to happen with bulbs blown by the mouth, unlefs they be kept fome weeks in a dry place, before they are filled. The fame danger makes it prudent not to boil Caution.

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

Trial of the proportion between the bulb and the tube.

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

Hermetical ſealing of the tube.

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

or

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

Proof of internal vacuum.

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

In

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Adjuftment of the fixed points.

In the original graduation of thermometers, two fixed points of temperature are neceffary. Thefe are the freezing point of water, or temperature of ice or fnow, at the inftant of formation, or rather when it is juft beginning to liquefy; and the boiling point of water, or temperature at which, under a known preffure, it is plentifully converted into fteam. For the fettling the freezing point, nothing more is neceffary than to immerfe the thermometer fo deep in melting fnow or ice, as that the mercury may be barely vifible above its furface, and carefully mark the place at which it ftands.

Freezing.

The boiling point is not quite fo eafily afcertained; crude, hard, or faline waters acquire a greater heat in boiling than fuch as are purer; and the fame water will acquire a greater heat under a greater preffure. For this laft reafon, the boiling point fhould be fixed according to the decifion of the committee of the Royal Society; namely, when the barometer ftands at 29.8 inches. The beft method is to provide a veffel fomewhat longer than the thermometer, with a cover, and two holes in it; one about an inch in diameter, for the fteam to efcape; and the other fmaller, for the thermometer tube to be faftened in it. When this is ufed, the thermometer muft be faftened in the cover, fo that the eftimated place of the boiling point may be juft above the hole. Water muft be put in the veffel, *not* fufficient to touch the bulb of the thermometer, when the cover fhall be put on. The veffel muft then be covered, a thin plate of metal laid on the fteam hole, and the water made to boil by heat applied to the bottom only. The thermometer will be then furrounded with fteam, which will raife its tem-

Boiling.

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

Adjuſtment for errors of the tube.

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

Standard thermometer.

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

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Cases in which the mercury need not be boiled.

The very careful boiling of the mercury, as above described, is absolutely necessary for such thermometers as are to be sealed when full: for if there were any air or moisture left in the bulb, it would prevent the mercury in the tube from descending into the bulb, so that the tube would continue always full. These thermometers are undoubtedly the best; but the vacuum above the mercury does not seem to be an indispensable requisite. If a clean dry tube be filled with pure boiled mercury, and a small bulb be left at the top of the tube, to contain common air, in order that its expansion or condensation, produced by the change in the mercurial surface, may be inconsiderable; there will be few practical objections against such a thermometer; more especially if it be a secondary instrument, graduated by means of a standard. There are some thermometers made with tubes so very small, and bulbs so large in proportion to them, that they will not admit of boiling the mercury in them, but are filled with boiled mercury by means of a condenser. These are necessarily of the kind here mentioned.

Scales of thermometers. Fahrenheit's.

The thermometers most in use at present are Fahrenheit's, Reaumur's, and Celsius's. In Fahrenheit's scale the number of degrees between the freezing and boiling water point is 180; the freezing point being at 32°, and the boiling point at 212°, both above 0°, or the part from which the degrees are reckoned both ways.

Reaumur's.

In Reaumur's scale the number of degrees between these two points is 80, and the freezing point is called 0°, from which the degrees are reckoned both ways.

Celsius's.

In Celsius's thermometer, the interval

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

THERMOMETERS.

Reduction of degrees of thermometers of various ſcales.

CHAP.

CHAP. IV.

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

APPLICAT. OF HEAT.

Friction; hammering; flint and steel.

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

Solar focus.

Chemical mixtures.

Combuftion.

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

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Combuftion.

which, if ignited in contact with the air of the atmofphere, will not lofe their ignition, but continue to give out heat, till their volatile parts are diffipated, and the properties of the remainder entirely changed. Thefe laft are called combuftible bodies. It is found by experiment that the capacities or quantities of heat, in combuftible bodies, are not confiderable; that the quantity of heat in atmofpheric air, in the elaftic ftate, is exceedingly great; and that part of this air is abforbed by bodies in combuftion. If, therefore, the temperature of a combuftible body be by any means fo raifed, as that the chemical procefs, by which air becomes condenfed and combined with it, may go on, the temperature of the air will be raifed, as its capacity is diminifhed, in paffing from the elaftic to the folid ftate; and it will therefore give out its heat to the combuftible body, which, inftead of becoming colder, muft increafe in temperature, in proportion to the quantity of air condenfed in the fame time, excepting fo far as this effect is diminifhed by the conducting power of the furrounding bodies.

Proceffes.

The proceffes which are performed by the fimple application of heat, are as follow:

Roafting.

Roafting.—This confifts in expofing mineral bodies to the heat of an open fire, for the purpofe of diffipating their volatile contents.

Calcination.

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

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

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

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

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

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

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

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

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

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the ufual temperature of the atmofphere, the vapours are fcarcely condenfed before they become folid. In this cafe the procefs is called fublimation; and the condenfed vapours, which ufually have a powdery form, are called flowers. Such are the flowers of brimftone, of benjamin, of zinc, &c. Solid products, obtained in this way, are called fublimates.

Flowers. Sublimates.

Common fire.

Some of thefe operations may be performed by a common culinary fire; and indeed moft of them may when the quantities of matter are fmall, which is ufually the cafe in philofophical experiments. In the arts, where every procefs requires to be repeatedly carried on in the large way, a variety of furnaces have been contrived, to fuit the various intentions of the operators. But experimental inquiries demand the occafional exertion of every branch of chemical operation; for which reafon, the furnaces and apparatus ought to be conftructed on as general principles as poffible.

Crucibles. See the plate.

The veffels ufed in chemiftry are—Fig. 1. Crucibles, or pots, made either of earth, black lead, forged iron, or platina. They are ufed for roafting, calcination, and fufion.

Cucurbits, or mattraffes.

Fig. 2. Cucurbits, mattraffes, or bodies, which are glafs, earthen, or metallic veffels, ufually of the fhape of an egg, and open at top. They ferve the purpofes of digeftion, evaporation, &c.

Retorts.

Fig. 3. Retorts are globular veffels of earthen ware, glafs, or metal, with a neck bended on one fide. Some retorts have another neck or opening at their upper part, through which they may be charged, and the opening may be afterwards clofed with a ftopper. Thefe are called tubulated retorts.

APPLICAT. OF HEAT.

Receivers.

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

Alembic—of glaſs;

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

—of metal.

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

Stills for ardent ſpirits.

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

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Furnaces.

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

Melting furnace.

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

Reverberatory furnace.

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

APPLICAT. OF HEAT.

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

Fuel.

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

Chemical bath.

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

Coating.

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

their figure in higher degrees of heat than they could ſuſtain without it. The materials are clay and fine ſand, well worked together into a paſte, and with the addition of ſome hair, ſuch as the bricklayers uſe. This is laid upon the veſſel in ſucceſſive thin coatings. APPLICAT. OF HEAT.

The joints or cloſures of veſſels are made tight by compoſitions called lutes. The clay and ſand uſed for coating, make a very good lute. In the diſtillation of ſubſtances which are not corroſive, it is found convenient to cloſe the junctures with paper, or linen, paſted on. Wet ſtrips of bladder may alſo be uſed in theſe caſes. Slacked lime and the whites of eggs form a good lute, which ſpeedily dries and becomes firm; but the compoſition called fat lute is uſed when the vapours are of a corroſive and volatile nature. This is compoſed of clay, firſt made very dry and pulverized, and then beat together into a paſte with linſeed oil which has been boiled upon litharge, and is known in the ſhops by the name of drying oil. Fat lute does not harden, but requires to be ſecured on its place by ſtrips of linen dipped in the lute made of lime and whites of eggs. Lutes. Fat lute.

The flame of a lamp with many ſmall wicks may be uſed in diſtillations that require a low heat. Lamp.

An ingenious ſtudent in chemiſtry, when he has familiarized himſelf with the firſt principles, will ſoon perceive that there are few philoſophical inquiries, if any, that require a large apparatus of furnace, or veſſels. A tobacco-pipe is a very uſeful crucible, in which a great number of operations may be performed in a common fire, eſpecially if urged with a pair of good double bellows. An earthen pot, or iron ladle, will contain a ſand-bath; and apothecaries phials, or Florence Facility of making experiments.

 flaſks,

flaſks, ſerve very well for mattraſſes. Chafing-diſhes, or ſmall iron ſtoves, may be applied to ſerve many uſeful purpoſes. And the blow-pipe and ſpirit-lamp, with a ſet of very ſmall retorts and receivers, may be adapted to the performance of almoſt every part of experimental chemiſtry.

Moveable furnaces.

The black-lead pots are very convenient for conſtructing a variety of moveable furnaces. They may be cut without difficulty by a ſaw whoſe teeth are ſet wide; and very eaſily admit of being ſcraped, drilled, or ground with ſand, to give them the requiſite figure. In Dr. Lewis's conſtruction, from whom the four following figures are taken*, the pots which are intended to be applied to each other, are ground flat upon a ſtone, with a little ſand; the holes are ſawed with the common compaſs-ſaw of the carpenters, and are made a little narrower externally than internally; by which means it is eaſy to fit them with ſtoppers made out of the broken pieces, that may be bought where the pots are ſold. Three or four hoops of copper-wire, about the thickneſs of a crow quill, and firſt ſoftened by heating it red-hot, are faſtened round the pots in the moſt convenient places, to render them more durable by keeping their parts together, after they may have been craked. A thin copper hoop ſerves to ſecure the place of junction of two pots.

Furnace for open fire.

Fig. 10, Repreſents a furnace for open fire formed by one pot. The lower ſquare aperture is the door of the aſh-pit, and the upper one the door of the fire-place, which, in the intentions this furnace is deſigned for, is

* Lewis's Philoſophical Commerce of Arts.

kept

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

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

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

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bottom of the diſtilling veſſel reſts on two bars laid acroſs within the lower pot. If the grate of this furnace be occaſionally changed for a larger, which may be placed near the edge of the lower pot, a muffle, or ſmall earthen oven, may be placed in the midſt of the fire, with its mouth oppoſite the hole in the iron hoop. In this may be performed all proceſſes that require the admiſſion of air, and frequent inſpection, ſuch as aſſays, enamelling, &c.

Moveable blaſt furnace.

Fig. 13, Is an improved blaſt furnace. The pot which contains the fuel for this purpoſe, has a number of holes bored at ſmall diſtances, in ſpiral lines, all over it, from the bottom up to ſuch an height as it is deſigned the fuel ſhall reach. The crucible is placed upon a proper ſupport in the bottom; and the holes are made, not in a perpendicular direction to it, but oblique, that the ſtreams of air forced in through them may but juſt touch it: by this means the crucible is in no danger of being cracked by the blaſt, and the impelled heat plays in a kind of ſpiral upon its ſurface. The lower pot receives this perforated pot to ſuch a depth that all its holes hang in the cavity; which cavity having no other outlet than the aperture for the bellows, the air blown in through this aperture neceſſarily diſtributes itſelf through the perforations of the inner pot. Both pots may be of the largeſt ſize, the external narrow part of the inner falling into the wide mouth of the outer. It wants no addition to its height; but, on the contrary, will be more commodious in regard to the inſpection and taking out of the crucible, if all the part above where the fuel reaches be ſawed away. The moſt convenient cover for it, is an iron plate with a round

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

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

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

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

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mouth, ſo as to interrupt the communication between the mouth and the paſſage of the noſtrils: by which means the operator is at liberty to breathe through the noſtrils, at the ſame time that, by the muſcles of the lips, he forces a continual ſtream of air from the anterior part of the mouth through the blow-pipe. When the mouth begins to be empty, it is repleniſhed by the lungs in an inſtant; while the tongue is withdrawn from the roof of the mouth, and replaced again in the ſame manner as in pronouncing the monoſyllable tut. In this way the ſtream may be continued for a long time without any fatigue, if the flame be not urged too impetuouſly; and even in this caſe no other fatigue is felt than that of the muſcles of the lips.

Flame urged by the blow-pipe.

A wax-candle of a moderate ſize, but thicker wick than they are uſually made with, is the moſt convenient for occaſional experiments; but a tallow-candle will do very well. The candle ſhould be ſnuffed rather ſhort, and the wick turned on one ſide towards the object, ſo that a part of it ſhould lie horizontal. The ſtream of air muſt be blown along this horizontal part as near as may be without ſtriking the wick. If the flame be ragged and irregular, it is a proof that the hole is not round or ſmooth; and if the flame have a cavity through it, the aperture of the pipe is too large. When the hole is of a proper figure, and duly proportioned, the flame conſiſts of a neat luminous blue cone, ſurrounded by another flame of a more faint and indiſtinct appearance. The ſtrongeſt heat is at the point of the inner flame.

The ſubject to be heated.

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

laid upon a piece of close-grained well-burned charcoal, unless it be of such a nature as to sink into the pores of that substance, or to have its properties affected by its inflammable quality. Such bodies may be placed in a small spoon made of pure gold, or silver, or platina.

APPLICAT. OF HEAT.

Advantages of the blow-pipe:

Many great advantages may be derived from the use of this simple and valuable instrument. Its smallness, which renders it suitable to the pocket, is no inconsiderable recommendation. The most expensive materials, and the minutest specimens of bodies, may be used in these experiments; and the whole process, instead of being carried on in an opake vessel, is under the eye of the observer from beginning to end. It is true that very little can be determined in this way concerning the quantities of products; but in most cases a knowledge of the contents of any substance is a great acquisition, which is thus obtained in a very short time, and will at all events serve to shew the best and least expensive way of conducting processes with the same matters in the larger way.

—its use rendered easy by bellows.

The blow-pipe * has deservedly of late years been considered as an essential instrument in a chemical laboratory; and several attempts have been made to facilitate its use by the addition of bellows, or some other equivalent instrument. These are doubtless very convenient, though they render it less portable for mineralogical researches. It will not here be necessary to enter into any description of a pair of double bellows fixed under a table, and communicating with a blow-pipe

* See Magellan's edition of Cronstedt's Mineralogy, or Bergmann's Chemical Essays.

which

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

Blow-pipe with vital air.

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

CHAP.

CHAP. V.

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

PROCESSES WITHOUT HEAT.

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

Apparatus for dense fluids.

— for elastic fluids.

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

PROCESSES WITHOUT HEAT.

Apparatus for experiments with elaftic fluids.

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

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

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

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

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

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

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

Phials with quickfilver.

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

Burning lens, or mirror.

Apparatus with mercury.

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

Combuftion of air.

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

upper-

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

Meaſuring tubes.

Where the change of dimenſions, which follows from the mixture of ſeveral kinds of air, is to be aſcertained, a graduated narrow cylindrical veſſel may be made uſe of. The graduations may be made by pouring in ſucceſſive equal meaſures of water into this veſſel, and marking its ſurface at each addition. The meaſure may be afterwards uſed for the different kinds of air; and the change of dimenſions will be ſhewn by the riſe or fall of the mercury, or water, in the graduated veſſel. The purity of common air being determinable by the diminution produced by the addition of nitrous air, theſe tubes have been called eudiometer tubes.

Eudiometers.

There are inſtruments called eudiometers, which conſiſt of an aſſemblage of parts adapted to the due mixture of theſe airs, and the accurate meaſurement of the change of bulk they undergo.

Management of powders.

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

Electric ſpark.

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

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Electricity applied.

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

Holes drilled in glaſs.

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

Impregnation of water;

The proceſs of impregnating water with any aerial fluid it will combine with, does not require any particular apparatus, but may be performed with ſuch utenſils as are every where to be met with. The moſt uſual operation of this kind is that of impregnating

—with fixed air.

water with fixed air; which may be done in the following manner. The quart bottle C, fig. 17, is filled with water, and inverted into the baſon F, which likewiſe contains a little water. The inverſion may be eaſily

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easily managed, without any of the contents of the bottle escaping, if its orifice be covered with a card, to be withdrawn after the immersion. A is a half-pint phial, into which broken pieces of marble or chalk are put; and upon them is poured as much water, rendered very acid by a mixture of oil of vitriol, as may fill the bottle two-thirds. B is a bladder, whose neck is tied fast round a perforated cork of a tapering figure. After the effervescence of the chalk and the acid has begun, the cork is to be thrust into the neck of the phial A, the bladder being previously emptied by pressure. Fixed air will escape from the chalk, and inflate the bladder. When this last is full, it must be disengaged from the bottle, and the bended tube E must be thrust into the orifice of its cork. The aperture of the tube being then placed beneath the mouth of the bottle C, it is easy to discharge the aerial contents of the bladder by pressure into this last. Agitation of the bottle C, without withdrawing its neck out of the water, increases the contact of the air and water, by dividing them into small parts, and by that means causes the absorption to take place in a few seconds. Two or three repetitions of this process impregnates the water so fully, that it will absorb no more in this way. The Pyrmont water is of this kind.

The use of the bladder, in this operation, is only to prevent any of the fluid contents of the bottle A from passing into the bottle C, which would happen in the violent state of ebullition, if the tube E were to pass directly from the bottle A to C. The manipulation is simpler if the bladder have two holes at its opposite

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

Dr. Nooth's apparatus.

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

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Dr. Nooth's apparatus:

that the fixed air, paſſing through the valve at H, aſcends into the upper part of the middle veſſel B, where, by its elaſticity, it re-acts on the water, and forces part up the tube into the veſſel A; part of the common air, in this laſt, being compreſſed, and the reſt eſcaping by the ſtopper, which is made of a conical figure, that it may be eaſily raiſed. As more fixed air is extricated, more water riſes, till at length the water in the middle veſſel falls below the lower orifice of the tube. Fixed air then paſſes through the tube into the upper veſſel, and expels more of the common air by raiſing the ſtopper. In this ſituation the water in both veſſels, being in contact with a body of fixed air, becomes ſtrongly impregnated with that fluid, after a certain time. This effect may be haſtened by taking off the middle and upper veſſels together, and agitating them.

—its valve defective.

The valve is the moſt defective part of this apparatus: for the capillary tube does not admit the air through, unleſs there be a conſiderable quantity condenſed in the lower veſſel: and the condenſation has, in ſome inſtances, burſt the veſſel.

Improvements in diſtillation.

Modern diſcoveries, reſpecting bodies in the aeriform ſtate, have produced ſeveral capital improvements in the veſſels uſed for diſtillation. It was common with the earlier chemiſts to make a ſmall hole in the upper part of their retorts, that the elaſtic vapours might eſcape, which would otherwiſe have burſt the veſſels. By this means they loſt a very conſiderable part of their products. Fig. 21, is an apparatus of veſſels *,

* Prieſtley, III.

VESSELS FOR DISTILLING.

Combination of receivers.

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

Improved receiver.

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

* By Mr. Woulfe. Prieftley, III.

ufually

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usually condensed in the receiver; and the other, at E, transmits the more volatile or aeriform products into a bason G, containing water; beneath the surface of which the extremity of the neck E is plunged. It is obvious that this apparatus is more particularly useful when the products are such as combine with the fluids in G, and would otherwise escape; and it is hardly necessary to observe, that a bottle, or other convenient vessel, may be substituted instead of the bason G.

Remedy against absorption.

It often happens in chemical processes, from the irregularity of the heat, or from other circumstances, that the condensation is more rapid, in proportion to the supply of vapour, at some periods of the same operation than at others. Whenever this takes place, the elasticity of the vapours will not be equal to the external pressure of the air; and if any orifice of the vessels, which are in other respects closed, be plunged in water, or any other fluid, this last will be pressed into the vessels. The remedy for this inconvenience is, to plunge the neck of the vessel to no greater depth in the water, than that the fall of the water, in the receiving vessel, may leave the orifice open for the admission of air, before the water has risen high enough above the orifice to reach the contents of the vessels. This effect is increased by making the neck large, in proportion to the diameter of the vessel which contains the water. Thus, if the neck E be made large, and the water from the bason G should, by a rapid condensation in C, be forced up the neck, the surface of the water in G will fall so much as to leave the lower orifice of E uncovered, before any considerable rise can

DISTILLATION.

take place; but if F were narrower, its whole capacity would be filled, and the water would run over into C before the fall in G would be fufficient to uncover the orifice of F, and reftore the equilibrium, by admitting common air. This obfervation applies to all chemical veffels, and is in no cafe more effential than when the neck of a fimple retort is plunged in water contained in a receiver.

Remedy againft abforption:

The above contrivance, which is Mr. Babington's, cannot very conveniently be applied to the apparatus Fig. 21, in which neverthelefs the condenfation of elaftic matter in the retort might occafion a difagreeable return of the fluids from the refpective bottles in fucceffion. Chaptal remedies this by a very fimple expedient. He has the tube of communication between A and B rather too fhort to reach the liquid in B; and through the bottom or upper part of this inverted receiver B he paffes a fmall tube open at both ends, and plunged into the liquid. This communication with the external air has no perceptible effect, as far as relates to any efcape of the vapours; though it effectually remedies the confequences of abforption.

—of Chaptal.

CHAP.

CHAP. VI.

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

THE BALANCE.

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

Balance described.

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

Points of suspension.

Fulcrum.

1. If

THE BALANCE.

Propositions.

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

2. If the center of gravity of the beam, when level, be immediately above the fulcrum, it will overset by the smallest action; that is, the end which is lowest will descend: and it will do this with more swiftness the higher the center of gravity, and the less the points of suspension are loaded.

3. But if the center of gravity of the beam be immediately below the fulcrum, the beam will not rest in any position but when level; and, if disturbed from that position, and then left at liberty, it will vibrate, and at last come to rest on the level. Its vibrations will be quicker, and its horizontal tendency stronger, the lower the center of gravity, and the less the weight upon the points of suspension.

4. If the fulcrum be below the line joining the points of supension, and these be loaded, the beam will overset, unless prevented by the weight of the beam tending to produce an horizontal position; as in § 3. In this last case, small weights will equilibrate, as in § 3; a certain exact weight will rest in any position of the beam, as in § 1; and all greater weights will cause the beam to overset, as in § 2. Money scales are often made this way, and will overset with any considerable load.

Money scales.

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

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

Propoſitions.

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

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

Weighing with a balance which is not equibrachial.

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

THE BALANCE.

either that the three edges be all truly parallel, or that the points of fufpenfion and fupport fhould be always in the fame part of the edge. This laft requifite is the moft eafily obtained.

Conftruction.

The balances made in London are ufually conftructed in fuch a manner, that the bearing parts form notches in the other parts of the edges; fo that the fcales being fet to vibrate, all the parts naturally fall into the fame bearing. The balances made in the country have the fulcrum edge ftraight, and confined to one conftant bearing by two fide plates. But the points of fufpenfion are referred to notches in the edges, like the London balances. The balances here mentioned, which come from the country, are inclofed in a fmall iron japanned box; and are to be met with at the Birmingham and Sheffield warehoufes, though lefs frequently than fome years ago; becaufe a pocket contrivance for weighing guineas and half guineas has got poffeffion of the market. They are, in general, well made and adjufted, turn with the twentieth of a grain when empty, and will fenfibly fhew the tenth of a grain, with an ounce in each fcale. Their price is from five fhillings to half-a-guinea; but thofe which are under feven fhillings have not their edges hardened, and confequently are not durable. This may be afcertained by the purchafer, by paffing the point of a penknife acrofs the fmall piece which goes through one of the end boxes; if it makes any mark or impreffion, the part is foft.

The turn.

9. If a beam be adjufted fo as to have no tendency to any one pofition, as in § 1, and the fcales be equally loaded; then, if a fmall weight be added in one of the fcales,

scales, that balance will turn, and the points of suspension will move with an accelerated motion, similar to that of falling bodies; but as much slower in proportion, very nearly, as the added weight is less than the whole weight borne by the fulcrum.

THE BALANCE.

Propositions.

10. The stronger the tendency to an horizontal position in any balance, or the quicker its vibrations, § § 3, 5, the greater additional weight will be required to cause it to turn or incline to any given angle. No balance therefore can turn so quick as the motion deduced in § 9. Such a balance as is there described, if it were to turn with the ten thousandth part of the weight, would move at quickest ten thousand times slower than a falling body; that is, the dish containing the weight, instead of falling through sixteen feet in a second of time, would fall through only two hundredth parts of an inch, and it would require four seconds to move through one third part of an inch: consequently, all accurate weighing must be slow. If the indexes of two balances be of equal lengths, that index which is connected with the shorter balance will move proportionally quicker than the other. Long beams are the most in request, because they are thought to have less friction. This is doubtful: but the quicker angular motion, greater strength, and less weight, of a short balance, are certain advantages.

Accurate weighing is slow.

Long beams.

11. Very delicate balances are not only useful in nice experiments, but are likewise much more expeditious than others in common weighing. If a pair of scales, with a certain load, be barely sensible to the one-tenth of a grain, it will require a considerable time to ascertain the weight to that degree of accuracy,

because

THE BALANCE. Propofitions.

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

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

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

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

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

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

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

Sets of weights.

Common pile.

Bifection.

Wire rings.

THE BALANCE.

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

Number of weights required to form a fet.

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

fyftem.

Decimal ſet of weights.

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

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

Account of ſome balances.

I ſhall conclude this chapter with an account of ome balances I have ſeen or heard of, and annex a able of the correſpondence of weights of different ountries.

The balance of Muſchenbroek:

Muſchenbroek, in his Cours de Phyſique (French ranſlation, Paris, 1769), tom. ii. p. 247, ſays, he ſed an ocular balance of great accuracy, which turned rebuchoit) with $\frac{1}{40}$ of a grain. The ſubſtances he eighed were between 200 and 300 grains. His ba- nce, therefore, weighed to the $\frac{1}{12000}$ part of the hole; and would aſcertain ſuch weights truly to four aces of figures.

— of Bolton.

In the Philoſophical Tranſactions, vol. lxvi. p. 509, ention is made of two accurate balances of Mr. olton; and it is ſaid that one would weigh a pound, d turn with $\frac{1}{10}$ of a grain. This, if the pound be oirdupois, is $\frac{1}{70000}$ of the weight; and ſhews that e balance could be well depended on to four places figures, and probably to five. The other weighed

F 2 half

THE BALANCE.

half an ounce, and turned with the $\frac{1}{100}$ of a grain. This is the $\frac{1}{24000}$ of the weight.

Balance of Mr. Read:

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

—of Mr. Whitehurft:

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

—of the Author:

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

—of Mr. Alchorne:

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

—of Dr. Geo. Fordyce.

A balance (made by Ramfden, and turning on points inftead of edges) in the poffeffion of Dr. George Fordyce

THE BALANCE.

dyce, is mentioned in the 75th volume of the Philosophical Transactions. With a load of four or five ounces, a difference of one division in the index was made by the $\frac{1}{1000}$ of a grain. This is $\frac{1}{384000}$ part of the weight; and, consequently, this beam will ascertain such weights to five places of figures, besides an estimate figure.

The balance of Mr. Magellan:

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

—of the Royal Society.

The Royal Society's balance, which was lately made by Ramsden, turns on steel edges upon planes of polished crystal. I was assured that it ascertained a weight to the seven millionth part. I was not present at this trial, which must have required great care and patience, as the point of suspension could not have moved over much more than $\frac{2}{100}$ of an inch in the first half minute: but, from some trials which I saw, I think it probable that it may be used in general practice to determine weights to five places and better.

Inferences.

From this account of balances the young student may form a proper estimate of the value of those tables of specific gravities, which are carried to five, six, and even seven places of figures, and likewise of the theoretical deductions in chemistry that depend on a supposed accuracy in weighing, which practice does not authorise. In general, where weights are given to five places of figures, the last figure is an estimate

or

THE BALANCE.

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

Comparifon of weights:

Among the numerous public exertions which our learned neighbours, the French, have made in favour of the fciences, the determination of the relative proportions of the weights ufed in various parts of Europe, is by no means one of the leaft. The moft exact ftandard weights were procured by means of the ambaffadors of France, refident in the various places; and

—by Monf. Tillet.

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

CHAP.

CHAP. VII.

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

AFFECTIONS OF BODIES.

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

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

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

Inertia of matter.

Extenfion.

ATTRACTIONS.

Gravity may perhaps be modified:

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

—but is not found to vary in experiments.

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

Uſual inference.

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

Effects of attraction:

—coheſive.

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

ATTRACTIONS.

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

Cohefive attraction differs from gravity.

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

Elective attraction.

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

Queftion.

ticles,

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Elective attraction does not depend on denfity.

ticles, that the particles of fpirit of wine are denfer than thofe of water. But, again, water diffolves gums; fpirit does not: whence, by the fame reafoning, we fhould deduce, that the particles of water are denfeft. But the true inference is, that if thefe different effects depend on any general law, it does not follow the denfity of the particles; and till that general law is difcovered, we ought to confider the various attractions which occur in chemiftry, as peculiar to the bodies in which they are obferved.

—probably on figure.

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

Aggregation.

The adhefion of parts of the fame kind, is called aggregation. Thus, a number of pieces of brimftone united by fufion, form an aggregate. The union of bodies of different kinds, in a grofs way, is called mixture. Thus fand and falt of tartar may be mixed together. But when the very minute parts of one body unite with thofe of another fo intimately as to form a body which has properties different from thofe of either of them, the union is called combination, or compofition. For example, fand and falt of tartar, expofed to a ftrong heat, combine, and form a compound called glafs. The minuteft parts into which an aggregate can be imagined to be divided without decompofition, are called integrant parts; but the parts into which it is divided by decompofition, are called component parts or principles.

Mixture.

Combination, or compofition.

Integrant and component parts.

Principles

Principles which cannot be ſubdivided by art, are called elements, or firſt principles; and the principles made up of theſe, are called ſecondary principles. Some writers carry this order ſtill farther; but it muſt be confeſſed that no means have yet been deviſed to ſhew unequivocally whether any ſuch ſubordination of principles exiſts. We may indeed diſcover the component parts of bodies; but we know nothing of their arrangement. Elements, or firſt principles.

As the chemical attractions, like other powers of the ſame kind, are weaker, the greater the diſtance between the parts which act on each other; and as heat enlarges the dimenſions of the bodies; doubtleſs, by ſeparating their parts, it will not be difficult to explain the effect of heat upon the changes produced in bodies by their elective attractions. Heat. See pag. 2, 3.

If two ſolid bodies, diſpoſed to combine together, be brought into contact with each other, the particles that touch will combine, and form a compound; and the proceſs will go no further, if the compound ſtill retain the ſolid form. But if the compound be of ſuch a nature as to have its point of congelation or ſolidity much lower than the temperature in which the experiment is made, or if it attract water from the atmoſphere, it will be fluid; and the eſſential property of a fluid being, that all its particles may freely move amongſt each other, the parts of each body will be at liberty to move in ſucceſſion, ſo as beſt to obey the elective attraction. The conſequence will be, that a new compound, in a fluid form, will be produced by the union of the two bodies. An inſtance of this has already been ſhewn in the mixture of ice and ſalt. Simple combination. Page 19.

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

CHEMICAL ATTRACTIONS.

Solvent, or menſtruum.

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

Water.

Cauſe of error in eſtimating the attractions.

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

Limits of ſaturation;

— in fluids:

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

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that power. For example, water, ſaturated with ſalt, will diſſolve ſugar; and water, ſaturated with fixed air, will diſſolve iron, though, without that addition, its action on that metal is ſcarcely perceptible. The word ſaturation is likewiſe uſed in another ſenſe by chemiſts: the union of two principles produces a body whoſe properties are different from thoſe of its component parts, but which reſemble thoſe of the predominating principle. When the principles are in ſuch proportion as that neither may predominate, they are ſaid to be ſaturated with each other; but if otherwiſe, the moſt predominant principle is ſaid to be underſaturated, and the other over-ſaturated.

—in general.

Solution aſſiſted by heat.

Fluids in general diſſolve a greater quantity of any ſubſtance the higher the temperature. This probably ariſes from the fluidity of the body in ſolution being promoted by the heat.

Medium of combination.

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

Separation, or precipitation.

It often happens, on the contrary, that the tendency to combination between a ſolvent and another body, is weakened or deſtroyed by the addition of a third. Thus ſpirit of wine weakens the action of water upon moſt ſalts, and of courſe ſeparates them from it. If to a ſaturated ſolution of nitre in water there be added an equal meaſure of ſtrong ardent ſpirit, the nitre becomes ſolid, and falls down in an inſtant to the bottom of the phial. The ſubſtance thrown down from a ſolvent by the addition of any other matter, is ſaid to be

CHEMICAL ATTRACTIONS.

be precipitated, and many fuch products are called precipitates.

Simple elective attraction.

When a compound of two principles is fo affected by the addition of a third, that a new compound is formed of this laft principle and one of the other two; at the fame time that the principle which was part of the original compound, but does not enter into the fecond combination, is difengaged; the decompofition and new combination are faid to be produced by fimple elective attraction or affinity.

Examples of fimple elective attraction:

Moft operations of nature or art are fo complex, that it is exceedingly difficult to exemplify thefe effects. The following inftance will exhibit an effect of fimple elective attraction, if we overlook the effect of the

— in the humid way:

water, which is prefent in both falts. Common falt confifts of two principles. The one is the mineral alkali commonly known by the name of falt of foda; and the other is the marine acid, which, when combined with water, is known by the name of fpirit of falt. If the vitriolic acid be poured upon common falt, it will attract the alkali more ftrongly than it is attracted by the marine acid. The confequence will be, that it will unite with the alkali, and form a new compound, called Glauber's falt, while the marine acid flies off in the form of air. This air, meeting with moifture in the atmofphere, combines with it, and forms the common marine acid vifible in the form of white fumes.

— in the dry way.

In the dry way, if a combination of lead and fulphur be fufed with iron, the fulphur unites with this laft, and leaves the lead free.

If we were to fpeculate on thefe events, it would

CHEMICAL ATTRACTIONS.

be eafy to fhew from what fuppofed action among the particles they may happen. If a particle of alkali be furrounded by particles of marine acid, and the vitriolic acid be added, the particles of thefe laft may be fo ftrongly attracted by the alkali as to approach it, and remove the particles of marine acid beyond the limit of fenfible attraction. This effect may be facilitated by the action of heat, which increafes the diftances between parts of bodies; and the difengaged fubftance may affume either the folid, fluid, vaporous, or aerial ftate, according to the temperature and the peculiar properties of the body itfelf in that refpect.

Double elective attraction.

Where two bodies, each confifting of two principles, are fo difpofed as to act on each other, and the order of the principles changes in fuch a manner as to form two other bodies compofed of different principles, the change is faid to be produced by double affinity, or double elective attraction.

Example: in the humid way:

In the humid way: Let mercury be diffolved in the nitrous acid (or fpirit of nitre of the fhops) until the acid will take up no more. The folution will then confift of a mercurial falt diffolved in water. Let tartar, which is a falt confifting of a peculiar acid united with the vegetable alkali, be added. The confequence will be, that the alkali of the tartar will quit its own acid, and, uniting with the nitrous acid, will form nitre, which will continue diffolved; and, on the other hand, the acid of the tartar, being difengaged, will unite itfelf to the mercury, and form a falt, which, on account of its infolubility, will fall down in the form of a powder.

— dry way.

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

CHEMICAL ATTRACTIONS.

fufed with the antimony of the fhops, which confifts of fulphur and a metallic body called regulus of antimony, the fulphur will unite with the copper, and float above, while the gold and the regulus combine together, and occupy the lower part of the crucible.

Numerical expreffion of affinity.

One of the principal objects of chemical refearch confifts in the numerical expreffion of the attractive powers of bodies. If this were well afcertained, it is probable we fhould be able to foretel, not only the effects of fimple or double affinity, but likewife in what cafes the compounds of three or more fubftances take place. See Appendix.

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

No regular connection has been yet difcovered between the folubility in water, the fufibility, volatility, fpecific gravity, and other obvious properties of the component parts of bodies, and of the compounds they produce. Hence it happens, in humid operations, that the infoluble products will either fall to the bottom, or rife to the furface, according to their weights. In fome proceffes, all the products will be thus feparated; and in others the whole will remain diffolved. In the dry way likewife fome products will rife, others will become fluid, and others fixed, fo as to require a ftronger heat to fufe them than before.

Utility of thefe changes.

Thefe feveral changes afford means to the chemift of feparating bodies from each other. When two different kinds of falt are diffolved in water, it would be almoft impoffible to feparate them if they were both equally foluble; becaufe evaporation would leave both in a confufed mafs. But where the one is more foluble than the other, the latter will begin to be feparated, and may be taken out at a period of the evaporation, at which

which the whole of the former will remain ſuſpended. So likewiſe the advantages derived from the proceſſes of diſtillation, ſublimation, and other dry operations, are founded on theſe different properties of bodies.

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Cryſtallization.

The parts of all bodies which take the ſolid ſtate are diſpoſed to arrange themſelves in ſuch a manner as to produce ſome regular geometrical figure in the ſolid. Thus ice, during its formation in water, or even in the open air, always aſſumes a regular figure, as far as circumſtances will permit. The ſame is obſervable in the fixation of other fluids, and alſo in the ſeparation of bodies from their ſolvents, as ſalts from water. This property is called cryſtallization, and the regularly-figured bodies are called cryſtals. The figure of cryſtals is influenced by ſo many circumſtances—ſuch as the quickneſs of their formation, the temperature and agitation of the fluid, the preſence of light, and others—that little dependence can be placed on it as an indication of the compoſition of bodies; though the experienced operator will doubtleſs derive ſome advantage by attending to it.

Polarity of the particles of bodies.

The regular arrangement of parts in cryſtallization is ſuppoſed by ſome to be the conſequence of a property in the particles of bodies, ſimilar to polarity in magnetiſm. And indeed it ſeems reaſonable to infer, that two compounded particles, coming together by attraction, undiſturbed by any other cauſe, ſhould diſpoſe themſelves ſo as to apply ſuch ſides of each together, as are occupied by principles the moſt attractive of each other.

BOOK II.

PARTICULAR CHEMISTRY.

SECTION I.

OF THE GENERAL PRINCIPLES OF BODIES.

CHAP. I.

CONCERNING THE GENERAL DIVISION OF CHEMICAL PRINCIPLES.

PRINCIPLES OF BODIES.

Arrangement.

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

PRINCIPLES OF BODIES.

Arrangement.

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

Enumeration.

The component parts of bodies are either,

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

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

proportion: these are vital air, phlogisticated air, and inflammable air. PRINCIPLES OF BODIES. Enumeration.

3. Water.

4. Earths.

5. Alkalis.

6. Acids.

7. Metals.

8. Mineral combustibles.

9. Parts of organized substances, whether obtained by mechanical pressure, by simple solution in water or ardent spirit, by a gentle or a strong heat, by the action of solvents, or by spontaneous decomposition.

Animal, vegetable, and mineral kingdoms.

The only general division of bodies at present referred to in the writings of modern chemists, is that by which they are classed into three kingdoms, called the animal, vegetable, and mineral kingdoms. The kind of bodies arranged in the two first kingdoms is obvious from the terms; and all other bodies are considered as belonging to the mineral kingdom.

Salts.

Alkalis, acids, and such compounds as they enter into, are distinguished generally by the name of salts. The leading character of salts is a strong tendency to combination, there being no bodies in nature which are not acted upon by some saline substance. This tendency appears in their eminent degree of solubility in water. All bodies known only by the name of salts, are soluble in less than two hundred times their weight of boiling water. The same cause produces their sapidity, or taste, which was regarded by the earlier chemists as a distinctive character of salts.

Metals are sometimes classed with combustible bodies; and, strictly speaking, they are combustible. But

PRINCIPLES OF BODIES.

Metals.

as none of them poſſeſs this property in ſuch a degree as to burn away in the common air, without the co-operation of other inflammable bodies, which are neceſſary to maintain their high temperature; and as they poſſeſs other remarkable properties peculiar to themſelves—they require to be placed in a ſeparate claſs.

CHAP.

CHAP. II.

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

IT has already been ſtated, that the exiſtence of heat, as a peculiar ſubſtance, is not proved; and, among philoſophers of the firſt eminence, there are ſeveral who think the opinion that it is a mere modification, is the moſt probable. With regard to light, the opinions of the world are leſs divided. It is generally taken for granted that light is a ſubſtance, or an emanation of particles of prodigious minuteneſs, which are projected in right lines, with extreme velocity, from luminous bodies; and that they are repelled from all bodies at certain diſtances, and at leſs diſtances attracted, ſo as to produce all the effects of reflection, refraction, and inflection, in the rays they compoſe. Theſe particles are ſuppoſed to be either of various magnitudes, or differently acted on by other bodies, and from that cauſe to be ſeparable from each other; in which ſeparate ſtate they affect the organ of ſight with the ſenſation of various colours.

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

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

Subtle fluid.

* It may be obſerved that this poſition is very doubtful. All our knowledge is derived from an obſervation of the actions which take place between bodies. Now we never ſee bodies act where

DOUBTFUL PRINCIPLES.

have thence inferred, that the univerſe is occupied by a ſubtle fluid, whoſe action cauſes bodies to approach and recede from each other in the phenomena of attraction and repulſion. Light is conſidered by ſome authors * as a modification of this fluid, in the ſame manner as ſound is admitted to conſiſt in an undulatory motion of the air, communicated from ſonorous bodies. We ſhall not here examine the merits of this queſtion, but ſhall only obſerve, that no deciſive experiments have yet been offered in ſupport of either opinion.

Light.

Burning lens, or mirror.

When a great number of rays of light are made, either by a burning glaſs or concave ſpeculum, to paſs through a ſmall ſpace, they excite a moſt powerful heat in bodies placed in the focus. The ſtrongeſt heat yet known is of this kind. The heat produced in bodies by the action of light, is in general greater, the more light is cauſed to diſappear. Bodies which either tranſmit or reflect the light in large quantities, are very little heated by the focus of a burning apparatus. Similar coatings of black paint, the one upon a plate of iron, and the other upon a plate of paſteboard, being expoſed in circumſtances perfectly ſimilar to the ſun's rays, the heat produced was greater in the iron, though the maſs

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

* Of theſe the great Euler ſtands firſt. See his Letters to a German Princeſs.

of

DOUBTFUL PRINCIPLES.

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

Light and heat differ.

Phlogiſton.

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

* Dr. George Fordyce, in Phil. Tranſ. Vol. LXXVII. p. 313.
† Scheele on Air and Fire, p. 70. Engliſh tranſlation.

had

DOUBTFUL PRINCIPLES.
Phlogiston.

had paffed from the one body to the other. It was indeed urged as an objection, that metallic bodies, fo far from lofing weight by calcination, do really become heavier: and later experiments fhewed that this increafe of weight was gained from the air; the abfolute neceffity of whofe prefence in combuftion had been formerly either overlooked, or flightly regarded. But this was explained from the doctrine of affinity, by the fuppofition that the pure air of the atmofphere, combining with the bafe of the combuftible body, fet its phlogifton, or fire, at liberty. The modern doctrine of heat however appears to fhew, that the increafe of temperature arifes from the air, and not from the combuftible body; and this confideration has led feveral eminent French chemifts to reject phlogifton altogether*, and to confider the procefs of combuftion as nothing elfe but the act of combination of vital air with the combuftible body; the matter of heat, which according to them is combined with the air, being fet at liberty.

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Among the chemifts who maintained the old opinion it became therefore an object of enquiry, whether the air abforbed in combuftion really either expels, or combines with, any principle common to all inflammable bodies. For if this fhould be refolved in the affirmative, the fubftance found would be the

* This doctrine may be feen difplayed at length in the notes annexed to Kirwan's Effay on Phlogifton, fecond edition. M. Lavoifier is the firft of the chemifts who explained and illuftrated the new doctrine by a fet of accurate experiments, and a judicious arrangement of the known facts; but M. Bayen may be confidered as the firft modern who, upon rational grounds, rejected the phlogifton. The excellent John Mayow is the father of this doctrine.

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

DOUBTFUL PRINCIPLES.

Phlogifton.

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

Queftion.

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

CHAP.

CHAP. III.

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

COMBUSTION.

Page 50.

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

Effects of combuſtion on common air.

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

Obſervations.

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

cannot therefore have received ſo much as it has loſt. The ſecond is the doctrine of the philoſophers who deny the exiſtence of phlogiſton, or a principle of inflammability. And the third muſt be adopted by thoſe who maintain that ſuch a principle eſcapes from bodies during combuſtion. This reſidue was called phlogiſticated air, in conſequence of ſuch an opinion.

Opinions.

Phlogiſton.

In the opinion that inflammable air is the phlogiſton, it is not neceſſary to reject the ſecond deduction. For the pure or vital part of the air may unite with inflammable air, ſuppoſed to be in a fixed ſtate in the combuſtible body; and if the product of this union remain fixed, it is plain that the reſidue of the air after combuſtion will be the ſame as it would have been if the vital part had been abſorbed by any other fixed body. Or if the vital air be abſorbed while the inflammable air is diſengaged, and unites with the aerial reſidue, this reſidue will not be heavier than before, unleſs the inflammable air it has gained exceeds in weight the vital air it has loſt.

Compoſition of the atmoſphere.

It is rendered more probable that the air of the atmoſphere conſiſts of a mixture of a vital and a noxious part, by the fact, that, when fixed bodies have been burned or calcined (for example, mercury converted into precipitate per ſe), the vital air may be again extricated from ſome of them. This is found to maintain combuſtion in the moſt effectual manner, and is almoſt totally abſorbed in that proceſs, inſtead of leaving a reſidue ſuppoſed to be changed by phlogiſtication. And, on the other hand, there is no unequivocal proof that vital air can be obtained from the phlogiſticated part by any operation whatever.

Vital

VITAL AIR.

Subftances which afford vital air.

Vital air may be obtained by heat from nitre, from alum, from mercury calcined without addition, and ufually called precipitate per fe; from red precipitate, from minium, from manganefe, and from lapis calaminaris. Moft nitrous and vitriolic falts afford it by heat. It is contained in the bladders of fea-weed, and in waters. The green vegetable matter formed in water emits it when expofed to the fun's light; and it is found in general that the leaves of plants, in like circumftances, emit vital air. Whence it appears that there are abundant provifions for reftoring the purity of the air, which is continually injured by combuftion, refpiration, fermentation, and other proceffes.

Refpiration is a procefs of the fame kind as combuftion.

The refpiration of animals produces the fame effect on air as combuftion does; and their conftant heat appears to be an effect of the fame nature. When an animal is included in a limited quantity of atmofpherical air, it dies as foon as the air is vitiated. Vital air, in like circumftances, maintains the life of animals much longer than common air.

Vegetables affect the air.

Vegetables do not thrive in vital air. Thefe appear to render common air purer, by abforbing its phlogifticated or noxious part. They emit vital air when the fun fhines on them. This is fuppofed to arife from the decompofition of water.

Nitrous air ufed as a teft.

Several of the metals, and other combuftible fubftances, when diffolved in fpirit of nitre, afford or extricate, by an effervefcence, a kind of air called nitrous air, of which we fhall more particularly fpeak in its place. Mercury is one of thefe metals. If this air be mixed with any other air in which vital air is contained, it unites with this laft, and forms red fumes, which

INFLAMMABLE AIR.

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

Subftances which afford inflammable air.

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

Water produced by combuftion of vital and inflammable air.

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

* By Morveau. See the Aeroftat de Dijon.

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

WATER.

Whether water be a compound.

usually holds a large proportion of water in solution, from which the aqueous product might be derived, it still remains a problem to be decided, whether water, with respect to the present state of our knowledge, be a simple or a compound substance. For the water may either be formed by the union of the two airs, or the real airs may be totally employed in forming the acid, while the water is simply condensed upon their losing the aerial form.

The extensive utility of water:

Water is a substance which enters into so many operations of nature and art, that a full description of its properties would include most of the properties of other bodies. Its weight is used as the measure of specific gravity; its capacity for heat is assumed as the standard of comparison for other bodies; its temperature at the changes from solidity to fluidity and to the elastic state, are taken as the fixed points for thermometers; and, in a word, the solubility of bodies denotes, in general, the action which this substance exerts upon them.

—its general properties.

Water being usually met with in these climates in the fluid state, its properties are in most cases treated of under that form. If it be heated it gradually expands, and is converted into vapour at 212° of Fahrenheit, with such rapidity as to counteract the effect of heat in raising its temperature. In a strong closed metallic vessel it may be heated nearly red hot, and in

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balances, none of which in practice weigh beyond five places of figures (p. 67—69), we shall find sufficient reasons to question the accuracy of conclusions, which suppose the quantities of air and water to be rigorously ascertained. These reasons are still more enforced by the consideration, that the experiments of Dr. Priestley and M. Lavoisier do not agree.

this ftate its folvent powers are greatly increafed. If the veffel be opened, fteam fuddenly rufhes out, and the temperature of the fluid falls inftantly to 212°. When water is cooled, it gradually contracts till within 8° of freezing, and then expands till it freezes. The parts of the water which firft become folid by freezing, have the form of fword-blades, croffing each other at angles of 60 degrees. It will fhoot out into this form in the open air, as may be feen in fnow or hoar froft upon trees. Ice is confiderably lighter than water, and therefore floats upon it. The expanfion of ice at the time of its formation is made with fuch force as to burft the ftrongeft metallic veffels: and the expanfion of fteam is prodigioufly great. This laft power, being very manageable, by transferring greater or lefs quantities of fteam into the veffels of apparatus, or by condenfing it, has been applied to the moft important mechanical ufes in the fteam engine, and will doubtlefs be applied to many more.

General properties of water.

Ice.

When water is included in a metallic globe or veffel, called the eolipile, which has only a very fmall aperture, and it is then made to boil, the fteam iffues out very violently, and will ftrongly urge a fire in the fame manner as bellows. This has been thought to prove a decompofition of the water. But it is not the fteam which excites the fire, but the air it drives before it. For an eolopile will not produce this, but the contrary effect, unlefs a body of air be interpofed between its aperture and the fire *.

Effects of the eolipile.

The denfity of water † is fuch that a cubic foot

Denfity of water.

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

† This was found by Cotes, who fays it is very nearly fo. See his Hydroftatical Lectures, p. 76, fecond edition.

 weighs

WATER.

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

Specific gravity of water.

What waters are pureſt.

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

CHAP.

CHAP. IV.

OF THE SIMPLE OR PRIMITIVE EARTHS.

EARTHS.

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

Five primitive earths.

New earths.

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

Stones.

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

Siliceous earth.

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

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

Pure ſiliceous earth.

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

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

Argillaceous earth.

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

Earth of alum.

Common clays.

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

EARTHS.

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

Pottery.

Thermometer for ftrong heat.

Calcareous earth:

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

* See Wedgwood in Phil. Tranf. Vol. LXXII, and LXXIV.

upon

EARTHS.

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

Method of obtaining it pure.

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

Lime, or quicklime.

Slaked lime.

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Mortar.

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

Gypſum, or plaſter of Paris.

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

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

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Animal earth.

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

Ponderous earth.

Ponderous fpar, or marmor metallicum.

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

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

fcarcely,

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ſcarcely, if at all, ſoluble in water. The liver ſtone, or lapis hepaticus, contains about one third part of this earth. If ponderous ſpar be fuſed with about twice its weight of fixed alkali, its acid will unite with this laſt, and form a ſalt, which may be waſhed off by water, the ponderous earth remaining behind in combination with fixed air. This may be deprived of its fixed air by a ſtrong heat, which converts it into a ſtate perfectly reſembling quick-lime in taſte, and exhibiting ſimilar phenomena with water.

To obtain pure ponderous earth.

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

Native aerated ponderous earth.

Though this earth reſembles lime in ſeveral reſpects, yet its combinations differ from thoſe of the latter, both in weight, and ſo many other reſpects, as evidently ſhew that there is no reaſon to conſider them as one and the ſame ſubſtance. It is combinable with acids.

This earth differs from lime.

From ſeveral properties in which ponderous earth has been obſerved to reſemble metallic ſubſtances, it has been ſuſpected to be of that claſs: but this ſuſpicion has not yet been verified by experiment.

Ponderous earth ſuppoſed to be metallic.

Moſt of the native ſpecimens of magneſian earth are remarkable for a certain ſoapy or greaſy feel. Of theſe the moſt common are, ſteatites, of a greeniſh colour, and ſoft enough to be ſcraped with the nail; ſoap rock; lapis ollaris, or Spaniſh chalk, of a yellow or whitiſh colour, but rarely black, rather harder than ſteatites, and ſo eaſily wrought and turned, that pots are

Magneſia.

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

The combination of vitriolic acid and magnefia is very foluble in water, in which it remarkably differs from the combinations of the fame acid with the calcareous or ponderous earths. This compound is known by the name of Epfom falt, and is found in fome waters; but is moft frequently obtained, for commercial purpofes, from fea water, after the common falt has been extracted by evaporation. If mild volatile alkali be added to a folution of Epfom falt, the alkali unites with the acid, and part of the earth falls to the bottom, combined with fixed air, which, when well wafhed, is mild magnefia. Epfom falt. Mild magnefia.

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

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

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

Suppofed reduction of the earths.

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

The new earths.

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

Characters of adamantine fpar:

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

* Journal de Phyf. 1790.

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

comes

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comes from China; it is cryſtallized in ſix-ſided priſms, without pyramids, varying in their length from half an inch to one inch, and in breadth near one inch; its colour is grey, of different ſhades. Whole pieces are opake, but thinner fragments are tranſparent: its texture is ſparry, and it breaks with a poliſh. The ſparry texture produces a ſlight ſtriated appearance on its ſurface: its hardneſs is ſo great, that it not only cuts glaſs like a diamond, but it marks rock cryſtal, and other hard ſtones: its ſpecific gravity is 3.710, and in ſome ſpecimens as high as 4.180. Small grains of magnetic calx of iron are ſometimes diſſeminated through this ſtone. —from China.

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

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

Analyſis of adamantine ſpar.

Peculiar earth.

* Various ſpecimens have been found in France. See De Morveau in the Annales de Chimie, i. 185.

there-

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

Characters of the jargon of Ceylon.

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

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

Peculiar earth.

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

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

neither

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neither did it, like them, form ſelenite or Epſom ſalt with vitriolic acid. It did not form alum with the vitriolic acid, as clay does. It differed eſſentially from ponderous earth, in its not being precipitable by the Pruſſian alkali; and in forming a ſalt with vitriolic acid, which was exceedingly different from ponderous ſpar. This earth was not ſoluble either in microcoſmic ſalt, or in mineral alkali, when treated by the blow-pipe; but borax diſſolved it. The jargon was found to contain in the hundred parts $31\frac{1}{2}$ ſilex, $\frac{1}{2}$ calx of iron containing nickel, and 68 of this peculiar earth.

Mineral from New South Wales:

A mineral from New South Wales was put into the hands of Mr. Wedgwood by Sir J. Banks *. It conſiſted of a mixture of fine white ſand, a ſoft white earth, ſome colourleſs micaceous particles, and a few black ones, reſembling black mica or black lead. Mr. Wedgwood made ſome experiments upon it, but does not appear to have completely analyſed the maſs, moſt probably on account of its ſmall quantity.

—ſubjected to experiments.

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

* Wedgwood in the Philoſ. Tranſ. for 1790, page 306.

8 ſolution,

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White earthy matter.

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

Marine folution of the white matter:

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

—fufibility.

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

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

Peculiar earth.

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

Other parts of the mineral.

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

CHAP. V.

OF THE SIMPLER SALTS; NAMELY, ALKALIS AND ACIDS.

ALKALIS.

Characters.

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

Vegetable fixed alkali.

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

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

Methods of procuring the vegetable alkali.

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

Purifying of alkalis.

 the

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the latter cafe, renders the weighing almoft impracticable.

Alkalis which contain fixed air, are called mild alkalis.

Alkali of nitre, called fixed nitre.

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

Purification of fixed alkali.

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

* Berthollet, in the Journal de Phyfique for 1786.

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

Oil of tartar.

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

Mineral alkali.

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

Water of cryſtallization.

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

Efflореſcence.

I 3

ALKALIS.

the air, are faid to effloresce; the pulverulent fubftance thus obtained is fometimes called an efflorefcence.

Abundance of mineral alkali; in fea falt.

Mineral alkali abounds in vaft quantities in the waters of the fea, where it forms half the weight of the common falt; and it is fometimes found in other natural combinations. The efflorefcence, or faline matter, which hangs upon old damp walls, confifts of this falt united to fixed air and water; and in many places in Afia and Africa it is collected at the furface of the earth.

—obtained by incineration.

The mineral alkali in trade is obtained by burning certain plants which grow on the fea fhore. It contains feveral neutral falts in fmall proportions, which may be feparated by cryftallization; as the alkali, being the moft foluble, remains fufpended in water longer than the reft. Sea falt may be decompofed, and its alkali obtained alone, but not fufficiently cheap for common ufes. Mr. Turner's procefs is faid * to confift in mixing a quantity of litharge (or calcined lead) with half its weight of common falt; which, after trituration with water till it affumes a white colour, is left to ftand fome hours: after which a decompofition enfues, the alkali becoming difengaged with water, while the acid unites with the metallic calx. This laft, by a proper degree of heat, produces a fine greenifh yellow pigment, the fale of which is the chief object of the manufacturer.

Turner's procefs with common falt.

The fixed alkalis are ftill confidered as fimple fubftances with regard to the prefent ftate of our knowledge. It is fufpected however that the fixed vegeta-

* Cronftedt's Mineralogy, by Magellan, Vol. I. p. 336.

ble

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ble alkali may confift of lime in combination with the fubftance called phlogifticated air; and that the mineral alkali is compofed of magnefia, united to the fame fubftance. The reafons for thefe fuppofitions are :—
* A fmall quantity of common nitre is produced by expofing wafhed chalk for fome months to the exhalations of putrid animal fubftances. The repeated diftillation of foap affords volatile alkali, and this contains phlogifticated air. And a portion of magnefia has been obtained by repeated folutions and calcinations of mineral alkali.

Cauftic folution of alkali:

Fixed alkalis, deprived of the fixed air they may contain, by boiling them for a fhort time with quick-lime, which has a ftronger attraction to the air, and becomes converted into chalk by the procefs, are then faid to be cauftic, becaufe they act with fuch energy as to corrode and deftroy animal fubftances. Soap lees is a folution of this kind; and the combination of a cauftic alkali with fat, or oil, is well known by the name of foap. If one part of lime, and two of falt of foda, be boiled in twelve parts of water for a fhort time, and the filtered lixivium be evaporated till its fpecific gravity be about 1.375, or, which is the fame thing, till a phial which would contain an ounce of water would contain an ounce and three eighths of the folution; the foap may be made by mere mixture of this lye with olive oil, in the proportion of one part of the former with two of the latter, in a glafs or ftone ware veffel. This mixture, being beat up from time to time with a wooden fpatula, foon becomes confiftent;

—or foap lees.

Soap.

* Thouvenel on Nitre. Chaptal's Elements of Chemiftry, I. 181. Eng. tranfl. and the authors by him cited.

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

Manufacture of foap in the large way.

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

Manufacture of glafs.

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

Difficulties.

upper,

pper, by the fubfidence of the heavier materials; circumftance which produces the appearance of hreads or veins in the work, on account of the dif- erent action of the feveral parts of the fame glafs on ie rays of light. The management of the heat is lfo a material point; for every increafe of heat extri- ates bubbles of fome elaftic fubftance; and if the glafs e ufed during this effervefcence, it will abound with ttle cavities which injure its tranfparency. The im- erfections of glafs are moft fenfibly felt in the con- ruction of optical inftruments, efpecially thofe which e called achromatic.

Frit.

To prevent the fwelling, at the firft combination of ie materials, they are previoufly mixed, and expofed r a confiderable time in a lower heat than is fuffi- ent to convert them into glafs; by which manage- ent great part of the more volatile matters are diffi- ted. This imperfect combination is called frit, and afterwards fufed by a ftronger heat. Glafs utenfils, nlefs very fmall, require to be gradually cooled in an ven. This operation is called annealing; and is ne- effary to prevent their cracking by change of tem- erature, wiping, or flight accidental fcratches.

Manufacture of fal ammoniac.

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

ALKALIS.

by the manufacturers, who diftil it from bones, or foot, or any other fubftance that affords it. To this they add the vitriolic acid, and alfo common falt, in due quantities. The vitriolic acid firft combines with the volatile alkali; but when the common falt, which confifts of fixed mineral alkali and marine acid, is added, a change of the principles takes place by double elective attraction. The vitriolic acid feizes the mineral alkali, and forms the new compound known by the name of Glauber's falt; while the marine acid unites with the volatile alkali, and forms fal ammoniac. By evaporation of the water, thefe falts are feparated by cryftallization, and the fal ammoniac is fublimed into cakes for fale.

Volatile alkali:

In order to difengage the volatile alkali from fal ammoniac by diftillation, it is neceffary to add fome fixed fubftance which fhall combine with and prevent the marine acid from rifing. Chalk and flaked lime are the bodies commonly ufed. If a mixture of two parts of chalk, and one of fal ammoniac in powder, be expofed to a fand heat in a retort, with a receiver adapted, a change of principles by double affinity takes place. The chalk, which confifts of lime and fixed air, is decompofed, and alfo the fal ammoniac. The lime unites with the marine acid, and forms a fixed earthy falt, which remains in the retort; and the fixed air unites with the volatile alkali, and paffes into the receiver, where it appears in the form of a white hard falt of a pungent fmell. This is the mild volatile alkali, or fal volatile of the apothecaries and perfumers. It is well known as a ftimulant ufually put into fmelling bottles.

—obtained by the medium of chalk:

When

ALKALIS.

—obtained by the medium of lime.

When lime, or calcareous earth deprived of fixed ir, is made ufe of, the decompofition takes place as efore; but the volatile product has a very different ppearance. It confifts, for the moft part, of a perma-ently elaftic or aërial fluid, which very readily com-ines with water, but may be confined in its elaftic tate in veffels over mercury. Moft of this product vas formerly loft, becaufe no more of it was detained n the veffels than had combined with the water which vas driven over by heat from the materials in the re-ort. But by the ufe of an apparatus upon the prin-iple of fig. 21, the air may be received and abforbed y water, without that great lofs which muft have rifen from the aërial fluid rifing long before the wa-er, and the quantity of this laft being infufficient to etain it.

Alkaline air.

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

Decompofition and formation of volatile alkali.

The volatile alkali is decompofed and formed again n many chemical proceffes. Thefe, generally fpeak-ng, require a more intimate knowledge of chemical facts

ALKALIS.

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

Characters of acids.

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

* Prieſtley, II. 239. V. 218. VI. 189.

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

The

Enumeration.
Mineral acids.

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

Vegetable acids.

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

Animal acids.

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

Inflammable additions to acids.

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

Theory.

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

ACIDS. Theory.

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

Vital air a component part of acids.

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

Neutral falts.

Combinations of alkalis with acids are called neutral falts.

CHAP.

C H A P. IX.

OF METALLIC BODIES IN GENERAL.

METALLIC ſubſtances are very eaſily diſtin- guiſhable from all other bodies in nature, by heir very great weight, and that opake ſhining ap- earance which is called the metallic ſplendour or rilliancy. Very few ſubſtances have half the ſpecific ravity of the lighteſt among the metals. They are ll fuſible, though at very different temperatures; and the fuſion be made in cloſe veſſels, they fix again by old, without having ſuffered any change but that of xternal figure, which muſt be produced in all bodies hich have been either liquefied or volatilized; namely, ey aſſume the form of the veſſel which contains them. ome of them may be extended conſiderably by the ammer, without breaking them. This property is alled malleability; and the metallic bodies which poſſeſs are called entire metals, or metals, in contradiſtinction ſuch as are more brittle, and are called ſemi-metals. Ietallic ſubſtances are alſo called perfect and imper- ct. The perfect are ſuch as undergo no laſting change their properties by any heat we can apply to them, leaſt in common furnaces. The imperfect metals, hen expoſed to a ſtrong heat, with acceſs of vital r, are changed, by a proceſs ſimilar to burning, and in me of them with an actual flame, into a brittle dull ıbſtance called a calx, which is heavier than the ıetal it came from, though its ſpecific gravity is not

CHARACTERS OF METALS.

Entire metals.

Perfect and imperfect metals.

Calces.

4 ſo

METALLIC SUBSTANCES.

Acids.

ſo great. Some are even converted into acids. If the calx of a metal be expoſed to ſtrong heat in a cloſed veſſel, with ſome inflammable matter, it recovers its metallic ſtate. This is called reduction or reviving of the metal.

Enumeration of metals.

All metals are imperfect except gold, ſilver, and platina. The imperfect metals are, mercury, lead, copper, iron, and tin; and the ſemi-metals are, biſmuth, nickel, arſenic, cobalt, zinc, antimony, mangaueſe, wolfram, molybdena, and uranite. The names arſenic, antimony, manganeſe, wolfram, and molybdena, being uſed to denote the mineral ſubſtance from which the ſemi-metals are obtained, the ſemi-metals

Regulus.

themſelves are diſtinguiſhed by the name of regulus of arſenic, regulus of antimony, and ſo forth; though modern chemiſts often uſe the ſimple term to denote the ſemi-metal itſelf alone.

Freezing point of metals.

Metals, like other fuſible bodies, have each a fixed temperature, or freezing point, at which they become ſolid. They aſſume a cryſtallized figure in cooling, which is different in each, and may be ſeen by fuſing them in melting pots with a hole in the bottom, ſtop-

Cryſtallization.

ped with a ſtopper; for in this caſe, if the ſurface be ſuffered to congeal, and the fluid metal beneath be ſuffered to run out through the hole, the under ſurface of the remaining metal will be curiouſly cryſtallized. The ſpecific gravity of metallic ſubſtances is very conſiderably affected by the gradual or haſty cooling, or tranſition from the fluid to the ſolid ſtate. Hammering renders them harder and more elaſtic; but this effect is deſtroyed by ignition.

Affinities.

The affinities of metals to each other are various. Some

Some will not unite at all; others mix very readily, and even combine together. On this property is founded the art of soldering; which consists in joining two pieces of metal together by heating them, with a thin piece or plate of a more fusible metal interposed between them. Thus tin is a solder for lead; brass, gold, or silver, are solders for iron, &c.

METALLIC SUBSTANCES.

Solders.

Mountainous districts, where the surface of the globe has been thrown up or disturbed, in remote ages, by earthquakes, volcanos, or other great convulsions of nature, are the most abundant in metallic bodies. In digging into the bowels of the earth, the various materials are mostly found disposed in strata or beds, which in plains lie level, but in mountains are inclined; whence it happens that in mountainous countries some strata are often exposed to the day, which would else have been too deeply lodged to be come at by human art. It is in the stratified mountains that metals are usually found, mostly in a state of combination either with sulphur or arsenic, or in the state of a calx. They are also found, though less frequently, in the metallic or native state.

Countries most abundant with metals.

The combinations, or earthy bodies, which contain metals in sufficient quantity to be worth extracting, are called ores. Iron ore sometimes forms entire mountains; but in general the metallic part of a mountain is very inconsiderable in proportion to the whole. The ores run either parallel to the stony strata, though far from having the same regularity of thickness, or they cross the strata in all directions. These metallic strata are called veins. The cavity formed by art in the earth, for the extraction of metals or any other mineral bo-

Ores. Veins. Mines. Matrix.

METALLIC SUBSTANCES.

dies, is called a mine. The ftone wherein a metallic ore is ufually bedded, is called its matrix. Thefe are not peculiarly appropriated to any metal, though fome ftones more frequently accompany metals than others.

Operations for extracting metals from ores.

The general operations by which metals are obtained from ores are—1. The minerals are felected; and fuch only are taken as from experience are known, by the external figure or appearance, to contain metal. 2. They are reduced to powder; and the lighter parts wafhed away, by means of water, in a fhallow trough. 3. The volatile parts are diffipated by the operation called roafting. 4. The ores are fmelted by throwing them into the midft of the fuel of a furnace, with earthy fubftances which are difpofed to run into glafs. In this operation, the glaffy matter, called fcoria, in fome meafure produces the effect of rendering the lower part of the furnace a clofed veffel; and the fuel revives the metal, which in the ore is ufually of the nature of calx. The revived metal being much denfer than the fcoria, falls to the bottom, and is fuffered to run out by proper openings. Thefe are the general operations, but they are not all neceffary in all cafes; and the particular practice with the feveral ores of each metal, muft vary according to the properties of the metal itfelf, and the different fubftances it is united with.

Affaying, or effaying.

The extraction of metals from ores, in the fmall way, which is neceffary to be made in order to afcertain whether the fpecimens are worth working, is called affaying or effaying. In thefe fmall trials the fufibility of the pounded ore is increafed by an addition of black flux, which is an impure alkali, formed

by

by mixing two parts of tartar with one of nitre, and fetting them on fire. Metallic ores may be very accurately affayed by folution and precipitation in the humid way.

Humid way.

Theory.

The theory of the calcination and reduction of metals, according to the fyftem of phlogifton, is as follows:—Metals, like all other inflammable bodies, contain phlogifton united to a bafe. While the vital part of the air unites with the bafe, the phlogifton is difengaged, and leaves behind it the combination called a calx, which is heavier than the metal, becaufe the air received exceeds the weight of the phlogifton difengaged.—In the antiphlogiftic fyftem, metals are confidered as fimple fubftances, which are converted into calces by their union with vital air, and are revived by heating them with any other matter which is more combuftible than themfelves; that is to fay, which has a ftronger attraction for vital air, at the temperature of reduction. Some of the maintainers of phlogifton admit that the vital air unites with that principle of inflammability, and compofes a fubftance which combines with the bafe of the metal. Here the fact agrees with the ftatement of the antiphlogiftians, but the explanation is lefs fimple.

Mixture of metals.

Moft metals will uniformly mix with each other; and the fpecific gravity of the compound is feldom fuch as would have been deduced from the fuppofition of a mere mixture, or fimple appofition of parts. Their fufibility is likewife greatly changed by mixture, and according to no certain rule yet difcovered.

Alloys.

Mixtures of metals are frequently called alloys. But the word alloy, or allay, is moftly ufed to denote a

METALLIC SUBSTANCES.

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

Solubility of metals in acids.

Metals are moftly foluble in acids, with which they form falts. When a metal is added to an acid, the general effect produced is the fame as would have arifen from the addition of any other combuftible fubftance to the acid.

Precipitation.

If an alkali or earth be added to a metallic folution, the metal falls to the bottom in the form of a calx. But if a metal which has a ftronger affinity with the acid than the metal already diffolved has, be added to fuch a folution, the former metal will fall to the bottom in its metallic ftate, and the latter will be diffolved without caufing any of the efcape of elaftic fluid, and other appearances, which would have taken place if it had been applied to the mere acid; notwithftanding which, the latter metal, if precipitated by an incombuftible fubftance, fuch as an alkali or earth, will be in the ftate of a calx.

Inferences.

It is evident, from thefe facts, that the action of acids upon metals is fimilar to that of heat with accefs of vital air; and of courfe may be accounted for, upon both the theories of chemiftry, in the fame manner as combuftion itfelf.

Original theory.

According to the original theory, when an acid acts upon a metal, it unites with the bafe of the metal, and expels the phlogifton; which either rifes alone, in the form of inflammable air; or, combining with the acid itfelf, forms an acid air, or volatile acid. If an alkali be added, the calx falls down, combined with air, which it obtains either from the alkali or the acid; but if a metal be added, the phlogifton of this laft, uniting with the calx of the former, revives it, and it falls down in its metallic ftate. The new theory

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

New theory.

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

Precipitation of metals by metals.

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

Limit of ſolution in acids.

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

Theory of solution.

Action of various substances on metals.

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

BOOK

BOOK II.

PARTICULAR CHEMISTRY.

SECTION II.

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

CHAP. I.

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

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

SULPHUR.

Pyrites.

colour of ſome ſpecimens, often lead the ignorant to ſuppoſe them rich in precious metal. The contents of the pyrites are various; but the kind here ſpoken of contains from one ſixth to one third of its weight of ſulphur, one eighth to five eighths iron in a calcined ſtate, and the reſt clay and ſiliceous earth. They give fire plentifully with the ſteel; whence their name is derived.

Diſtillation of ſulphur:

A moderate heat will expel the ſulphur from pyrites, as it is conſiderably volatile. In the large way, in Germany and Italy, the pyrites are put into earthen cucurbits, diſpoſed in a furnace in ſuch a manner that when the ſulphureous part melts, it runs into veſſels filled with water, and there congeals.

—ſublimation,

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

Action of water upon ſulphur.

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

* Prieſtley, VI. 150.

The

SULPHUR.

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

Combination of ſulphur; with lime:

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

—with ponderous earth:

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

—with magneſia.

and

SULPHUR.

and the water will contain a magnesian liver of sulphur; from which the earth may be precipitated by the addition of an alkali, which will unite with the sulphur; or the sulphur may be precipitated by an acid, which will combine with the earth.

Combination of sulphur with fixed alkalis.

The fixed alkalis combine very readily with sulphur, either in the moist or dry way, whether they be in a pure or caustic state, or combined with fixed air; though more strongly in the former than the latter case. If a solution of fixed alkali in water be boiled with half its weight of powdered sulphur, a combination takes place, and liver of sulphur is formed. Or, if equal parts of dry alkali and powdered sulphur be melted in a crucible, and poured out on a flat polished stone, as soon as the fusion is complete, the combination will be of a liver colour, and is the solid hepar. If it be made with a pure or caustic alkali, its colour is deeper, and its characteristic properties more intense, than when a mild alkali is used. A solution of the solid hepar in water forms precisely the same substance as the preparation made in the moist way.

Hepatic air.

The peculiar fetid smell of the solid hepar when moistened, or of its solution, is produced by the emission of a permanently elastic fluid, called hepatic air. This smell, when strong, is insupportable, and suddenly destroys animal life. Hepatic air is very soluble in water, which it converts into a state perfectly resembling that of the sulphureous mineral springs. It renders syrup of violets green, blackens the calces of lead and bismuth, and the surface of silver. Vital air decomposes it, and causes sulphur to be deposited. It

deto-

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

SULPHUR.

Hepatic air.

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

Volatile liver of sulphur.

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

Balsams.

* Hassenfratz in Phil. Trans. Vol. LXXVII. p. 306.

When

SULPHUR.

Combuftion of fulphur.

When fulphur is heated in an open veffel, it melts; and foon afterwards emits a blueifh flame, vifible in the dark; but which, in open day light, has the appearance of a white fume. This flame has a fuffocating fmell; and has fo little heat that it will not fet fire to flax, and may even be fuffered to play againft the palm of the hand without any confiderable inconvenience. In this way the fulphur may be entirely confumed. If the heat be ftill augmented, the fulphur boils, and fuddenly burfts into a much more luminous flame; the fame fuffocating vapour ftill continuing to be emitted.

Volatile vitriolic acid.

The fuffocating vapour of fulphur is imbibed by water, with which it forms the fluid called volatile vitriolic acid. If this fluid be expofed for a time to the air, it lofes the fulphureous fmell it had at firft, and the acid becomes more fixed. It is then the fluid which was formerly called fpirit of vitriol. Much of the water may be driven off by heat; and the denfe acid which remains is the vitriolic acid, commonly called oil of vitriol: a name which was probably given to it from the little noife it makes when poured out; and the unctuous feel it has when rubbed between the fingers, produced by its corroding and deftroying the fkin, with which it forms a foapy compound.

Oil of vitriol.

Vitriol of iron.

The pyrites before mentioned, which confift, for the moft part, of fulphur and iron, are found to be converted into the falt called vitriol of iron by expofure to air and moifture. In this natural procefs the pyrites break, and fall in pieces; and if the change take place rapidly, a confiderable increafe of temperature follows, which is fometimes fufficient to fet the

mafs

maſs on fire. By conducting this operation in an accurate way, it is found that vital air is abſorbed. The vitriol is obtained by ſolution in water, and ſubſequent evaporation; by which the cryſtals of the ſalt are ſeparated from the earthy impurities which were not ſuſpended in the water.

Diſtillation of vitriol.

The vitriolic acid was formerly obtained by diſtillation from vitriol of iron. When this ſalt is expoſed to heat, the vitriolic acid comes over, at firſt attended with a large quantity of volatile ſulphureous vapour; and, towards the end, there is a production of pure dephlogiſticated air. The acid which riſes laſt has a concrete cryſtalline form. The acid obtained in this proceſs is black, and requires to be purified by a ſecond diſtillation, or rectification, in which the volatile ſulphureous acid comes over, and leaves the denſe vitriolic acid behind.

Manufacture of vitriolic acid.

Moſt of the vitriolic acid now uſed is produced by the combuſtion of ſulphur. There are three conditions requiſite in this operation. Vital air muſt be preſent, to maintain the combuſtion; the veſſel muſt be cloſe, to prevent the eſcape of the volatile matter which riſes; and water muſt be preſent, to imbibe it. For theſe purpoſes, a mixture of eight parts of ſulphur with one of nitre is placed in a proper veſſel, incloſed within a chamber of conſiderable ſize, lined on all ſides with lead, and covered at bottom with a ſhallow ſtratum of water. The mixture being ſet on fire, and ſhut up, will burn for a conſiderable time, by virtue of the ſupply of vital air which nitre gives out when heated; and the water, imbibing the ſulphureous vapours, becomes gradually more and more acid, after repeated com-

VITRIOLIC ACID.

combuſtions; and the acid is afterwards concentrated by diſtillation.

Characters of vitriolic acid.

Pure vitriolic acid is colourleſs, and emits no fumes. It ſtrongly attracts water, which it takes from the atmoſphere very rapidly, and in large quantities, if ſuffered to remain in an open veſſel. If it be mixed with water, it produces an inſtantaneous heat, nearly equal to that of ebullition. Its action upon all the earths except the ſiliceous, upon the alkaline ſalts, upon many metals, and almoſt every other combuſtible ſubſtance, is very ſtrong.

Combination of vitriolic acid and clay.

With argillaceous earth it forms alum. This well-known ſalt has a peculiar auſtere or aſtringent taſte; is ſoluble in about fifteen times its weight of water, at the temperature of 60°, and in a much leſs quantity at higher temperatures; from which it may be ſeparated in the form of permanent cryſtals. It fuſes at a moderate heat, and froths up till its water of cryſtallization is evaporated; at which period it has the form of a white friable ſubſtance, called calcined alum, which retains the greateſt part of its acid when not too much heated; and may again be reſtored to its original form by adding the water it had loſt by the heat.

Preparation of alum.

Alum is not made for the purpoſes of commerce by a direct combination of the vitriolic acid and clay, but is extracted from ſubſtances uſually called alum ores, which either are, or probably were originally, compoſed of clay and ſulphur. From ſuch as contain the alum ready formed, as is the caſe with earths of this kind found in the neighbourhood of volcanos, it is extracted by lixiviation in water, and ſubſequent evaporation. But other ſubſtances, ſuch as pyrites and

alum

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

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

Vitriolic acid with lime, p. 104.

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

—with ponderous earth, p. 105:

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

—with magnefia, p. 106:

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

—with vegetable alkali.

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

VITRIOLIC ACID.

Vitriolic acid with mineral alkali:

With the mineral or marine alkali, the vitriolic acid forms Glauber's ſalt, which requires only three times its weight of water to diſſolve it at the ſame temperature. It is more ſoluble in hot than cold water; and may therefore be ſeparated from a hot ſaturated ſolution, either by cooling or by evaporation. Its cryſtals are uſually large and well formed; but they loſe their water of cryſtallization, which amounts to near half their weight, by expoſure to the air, and fall into an efflorefcence, or white powder.

—with volatile alkali:

The combination of the vitriolic acid with volatile alkali, is called vitriolic ammoniac. It is ſoluble in twice its weight of cold or an equal weight of hot water; and affords cryſtals either by cooling or evaporation, which are permanent, or ſlightly diſpoſed to attract moiſture and deliqueſce. Some chemiſts aſſert that it is volatile, and others affirm the contrary. Upon examination, it would probably be found that the acid or alkali, or both, are decompoſed by heat.

—with combuſtible matter.

Aeriform vitriolic acid.

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When any combuſtible ſubſtance is added to the concentrated vitriolic acid, the fluid becomes black; and emits white vapours, which are of an exceedingly pungent ſulphureous ſmell; and, if received over mercury, are found to conſiſt of a peculiar aeriform fluid, which is not condenſable into the fluid ſtate except by a very great degree of cold *. It is ſoluble in water, which it converts into volatile vitriolic acid, of exactly the ſame nature as that obtained by the combuſtion of ſulphur. Whence it follows, that the fumes of ſulphur conſiſt of this kind of air, rendered viſible by

* This was effected by M. Monge. See Fourcroy's Chemiſtry, Vol. I. p. xxxi.

the

VITRIOLIC ACID.

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

Sulphureous acid.

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

Characters of vitriolic acid air.

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

Vitriolic acid converted into ſulphur.

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

* Prieſtley, IV. 124.

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

Stahl's experiment for obtaining fulphur from vitriolic acid.

Electricity.

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

Recapitulation and theory.

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

to

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Theory.

to be. The combuftion of fulphur is of the fame nature as every other combuftion. Vital air is abforbed, and the inflammable principle is fuppofed to be extricated. The fulphur, thus deprived of its phlogifton, and united to vital air, becomes an acid; which is not completely changed until, by fubfequent expofure to the common air, it has imbibed ftill more of the vital part, and the remaining phlogifton has been diffipated. The decompofition of pyrites is a phenomenon of the fame kind, but is performed more gradually, and of courfe with the accumulation of lefs heat. The fulphur of thefe combinations attracts the vital part of the air by an action which is fuppofed to be increafed by the ftrong tendency of the iron to combine with the acid that refults from the union; the phlogifton being diffipated for the fame reafon. Inftead, therefore, of a combination of iron and fulphur, they become converted into vitriol, in which an acid is found: and as this procefs confifts of the abforption of vital air, and difengagement of phlogifton, it is a true combuftion; with this only modification, that the heat is feldom extricated fo rapidly as to produce the appearances of ignition and flame, but is conducted off by the furrounding bodies nearly as faft as it is generated.

Decompofition of pyrites.

Black vitriolic acid.

In the diftillation of vitriolic acid from vitriol of iron, the acid is rendered black and fulphureous from the iron, which was not completely dephlogifticated or calcined during its original combination with the acid: for the phlogifton of the iron is fuppofed, in this diftillation, to unite with the acid, and form fulphur; while the portion of the vital air which con-

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

Mutual action of vitriolic acid and combuftible bodies.

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

Liver of fulphur from vitriolated tartar.

An explanation nearly fimilar may be applied to the formation of liver of fulphur, when vitriolated tartar is fufed with an alkali and charcoal. Vitriolated tartar

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confifting of vegetable alkali united to vitriolic acid, is decompofed by charcoal. This uniting with the vital air of the acid, at the fame time that it communicates its phlogifton to the bafe, converts the acid into fulphur: the additional alkali ferves only to affift the fufion of the original mafs, and to prevent the diffipation of the fulphur by combining with it.

Antiphlogiftic theory.

Thus far we have admitted the inflammable principle in our explanation; and it muft be admitted, if it can be fhewn that fulphur contains it. We muft confefs however that this has not been proved; and that inflammable air has never been obtained directly from fulphur, except a fmall quantity, by paffing fteam of water over it when heated in an earthen tube *; in which cafe the original doubt prefents itfelf, whether the air come from the fulphur or the water. The modern theory, which rejects phlogifton, accounts for the preceding facts fimply by the abforption or extrication of vital air. Sulphur is taken to be a fimple fubftance. The combuftion of fulphur confifts of the rapid combination of that fubftance with vital air; which, at the fame time, gives out its heat as its capacity is diminifhed. A fmaller proportion of vital air, with the fulphur, compofes the volatile vitriolic acid, whether in the aerial form, or mixed with water: a larger dofe forms the complete vitriolic acid. If a combuftible body be added to vitriolic acid, this body becomes burned, or calcined, by uniting with part of the vital air of the acid; the remainder confequently has an over-proportion of fulphur, and therefore becomes volatile. If the abforption of pure air be fuf-

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* Prieftley, VI. 150.

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

Detonation of hepatic air.

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

CHAP.

CHAP. II.

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

NITROUS ACID.

Production of nitre.

THE nitrous acid is obtained from the falt called nitre or faltpetre, which confifts of the acid itfelf united to the vegetable alkali. This falt is never found in confiderable quantities in nature, but is evidently produced by a concurrence of circumftances. The nitrous acid appears to be produced in all fituations where animal matters are completely decompofed, with accefs of air, and of proper fubftances with which it can readily combine. Grounds frequently trodden by cattle, and impregnated with their excrements; or the walls of inhabited places where putrid animal vapours abound, fuch as flaughter-houfes, drains, or the like, afford nitre by long expofure to the air. Artificial nitre beds are made by an attention to the circumftances in which this falt is produced by nature. Dry ditches are dug, and covered with fheds, open at the fides, to keep off the rain: thefe are filled with animal fubftances—fuch as dung, or other excrements, with the remains of vegetables; and old mortar, or other loofe calcareous earth, this fubftance being found to be the beft and moft convenient receptacle for the acid to combine with. Occafional watering, and turning up from time to time, are neceffary to accelerate the procefs, and increafe the furfaces to which the air may apply. After a fucceffion of many months, more or lefs, according to the management of the operation,

Nitre beds.

NITROUS ACID.

nitre is found in the mafs. If the beds contained much vegetable matter, a confiderable portion of the nitrous falt will be common faltpetre; but, if otherwife, the acid will, for the moft part, be combined with the calcareous earth.

Extraction of faltpetre.

To extract the faltpetre from the mafs of earthy matter, a number of large cafks are prepared, with a cock at the bottom of each, and a quantity of ftraw within, to prevent its being ftopped up. In thefe the matter is put, together with wood-afhes, either ftrewed at top, or added during the filling. Boiling water is then poured on, and fuffered to ftand for fome time; after which it is drawn off, and other water added in the fame manner, as long as any faline matter can be thus extracted. The weak brine is heated, and paffed through other tubs, until it becomes of confiderable ftrength. It is then carried to the boiler, and contains nitre and other falts; the chief of which is common culinary falt, or the marine acid united to the mineral alkali, or fometimes to magnefia. It is the property of nitre to be much more foluble in hot than cold water; but common falt is foluble very nearly as much in cold as in hot water. Whenever, therefore, the evaporation is carried by boiling to a certain point, much of the common falt will fall to the bottom, for want of water to hold it in folution, though the nitre will remain fufpended by virtue of the heat. The common falt thus feparated is taken out with a perforated ladle; and a fmall quantity of the fluid is cooled, from time to time, that its concentration may be known by the nitre which cryftallizes in it. When the fluid is fufficiently evaporated, it is taken out and cooled, and great part

part of the nitre ſeparates in cryſtals; while the remaining common ſalt continues diſſolved, becauſe equally ſoluble in cold as in hot water. Subſequent evaporation of the reſidue will ſeparate more nitre in the ſame manner.

Purification of nitre.

This nitre, which is called nitre of the firſt boiling, contains ſome common ſalt; from which it may be purified by ſolution in a ſmall quantity of water, and ſubſequent evaporation: for the cryſtals thus obtained are much leſs contaminated with common ſalt than before; becauſe the proportion of water is ſo much larger, with reſpect to the ſmall quantity contained by the nitre, that very little of it will cryſtallize. For nice purpoſes, the ſolution and cryſtallization of nitre are repeated four times. The cryſtals of nitre are uſually of a priſmatic form.

Decompoſition of nitre by heat.

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

Deflagration of nitre.

When a combuſtible body and nitre are brought into contact, either of them being previouſly heated red hot, the body is burned with great rapidity, no doubt by the vital air which the nitre affords by the heat; for the experiment ſucceeds in vacuo, and alſo when

NITROUS ACID.

when the bodies are furrounded by any aerial fluid incapable of maintaining combuftion. This rapid combuftion, effected by means of nitre, is called defla-gration, when it is performed by a fucceffive burning of the parts of the body; or detonation, when the com-buftion of the whole is performed in fo fhort a time as to appear inftantaneous. In this experiment it is remarkable that the combuftion is maintained by vital air which is not in the elaftic ftate, but fixed in the nitre. Whence it fhould follow, that either the vital air, or the combuftible body, even in the fixed ftate, has a great capacity for heat, of which it muft contain a large quantity, on the hypothefis of heat being matter. Or, if heat be a mere commotion, it will follow, that though the quantity of agitation produced by the fud-den coalition of particles, in the act of converting an elaftic fluid into a denfe body, be fuch as to produce a great effect in increafing the temperature; yet the quantity is ftill fo confiderable, when vital air and combuftible matter unite even in their denfe ftate, as to caufe the moft intenfe degree of ignition.

Detonation.

Invention of gunpowder.

This property of nitre has been applied to the pro-duction of a fubftance which has greatly affected the habits of human fociety, particularly in thofe wars which unfortunately their vices too often produce. The invention of gunpowder has totally changed the military fyftem of nations; and has probably fuppreffed much of that malice and inveterate rancour which actuate the minds of combatants who meet hand to hand, inftead of managing the inftruments of indifcri-minate flaughter at a diftance. This deftructive pow-der is compofed of feventy-five parts by weight of

nitre,

NITROUS ACID.

Composition of gunpowder.

nitre, sixteen of charcoal, and nine of sulphur, intimately blended together by long pounding in wooden mortars, with a small quantity of water. This proportion of the materials is the most effectual; but the circumstance on which its effect more particularly depends is, the accurate mixture of the parts. Gunpowder is granulated by making the mass into a stiff paste, and agitating it upon a wire sieve, which cuts it into small parts; and these being shaken, or rolled in a barrel, take a rounded form by their mutual friction against each other. When any grain of a heap of gunpowder is set on fire, the detonation begins, and is propagated with amazing rapidity through the interstices of the grains; a large quantity of permanently elastic fluid, consisting of one-third fixed air, and the rest phlogisticated air *, being at the same time produced. The expansion of the elastic products is the cause of the well-known effects of gunpowder. It is said that gunpowder is much weaker for being granulated. If the grains be pulverized, it is certain that the effect is much less, on account of the inflammation being propagated more slowly; but the assertion may nevertheless be true of powder which is newly made, and has never been grained. Gunpowder which has been suffered to become damp, scarcely ever recovers its former force; most probably because the nitre, by a partial solution, becomes separated from the mass in more distinct saline crystals than before; and the wetting, which is necessary to the process of granulating, may weaken the powder in the same way.

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

When

NITROUS ACID.

Fulminating powder.

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

Diftillation of nitrous acid.

If clay, bole, or alum, be mixed with nitre, and expofed to diftillation, the nitre is decompofed, and the acid comes over; the attraction between itfelf and the alkali being weakened, partly by the attraction which the vitriolic acid ufually contained in thofe bodies has for its alkali, and partly by the attraction exerted between the fame alkali and the filiceous earth of the clay. If ftrong vitriolic acid be added to nitre in a retort, the fame decompofition takes place with the application of much lefs heat, by virtue of the fuperior attraction of the acid of vitriol to the alkaline bafe.

Nitrous

NITROUS ACID.

Nitrous acid is ufually yellow, and emits fuffocating fumes of the fame colour; but it may be rendered pure and colourlefs by a flight boiling in a retort. Aqua fortis is a weak fpirit of nitre, and not remarkably pure. It ufually contains fome marine acid.

The affayers purify their nitrous acid by adding a fmall portion of the nitrous folution of filver. This metal unites with the marine acid it may contain, and falls down in the form of an infoluble compound. Care muft be taken to avoid adding too much.

Nitrous acid; with lime:

This acid, in combination with calcareous earth, forms a falt whofe cryftals deliquefce by expofure to the air. It is foluble in twice its weight of cold, or its own weight of boiling water. With ponderous earth, it forms a falt of difficult folubility. With magnefia it forms an acrid bitter falt, which is very foluble in water, and deliquefcent in the air. With clay it forms an auftere falt of difficult folution. None of thefe have yet been applied to any ufe.

—with ponderous earth; magnefia:

—and clay:

—with mineral alkali:

With the mineral alkali this acid forms a falt called quadrangular nitre, from the ufual form of its cryftals. About three times its weight of water is required to hold it in folution in a mean temperature, and it is fcarcely more foluble in hot water. Its properties refemble thofe of common nitre; but it is lefs fit for making gunpowder, becaufe it attracts the humidity of the air.

—with volatile alkali.

The nitrous acid, in combination with the volatile alkali, forms nitrous ammoniac; a falt which flightly attracts the humidity of the air, and is foluble in lefs than its own weight of water. If this falt be expofed to heat in clofed veffels, it fuddenly explodes; part of the

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the acid and alkali is deſtroyed; and the aerial product is phlogiſticated air.

Production of nitrous acid.

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

Nitrous acid produced; by Mr. Cavendiſh:

—by M. Thouvenel.

Inference.

* For the detail of the particulars of this moſt curious experiment, conſult Mr. Cavendiſh's papers, in the Phil. Tranſ. Vol. LXXV. p. 372; and Vol. LXXVIII. p. 255.

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

account

account of its being lefs combuftible, the red heat cannot be produced and kept up without the co-operation of electricity: and as fulphur, when in contact with the pure air of the atmofphere, and with a bafe proper for combining with the vitriolic acid, is converted into that acid by a flow combuftion in the pyrites; fo the like expofure of phlogifticated air, in contact with calcareous earth, to vital air, produces nitrous acid, though much more flowly, becaufe the bafe is lefs combuftible. NITROUS ACID.

The nitrous acid acts with peculiar energy on combuftible fubftances, which it burns or calcines; and during moft of thefe proceffes a peculiar kind of air flies off, which is called nitrous air. It is produced by the folution of many of the metals, by moft vegetable, and fome animal fubftances. This aërial fluid is not rapidly imbibed by water, and may therefore for temporary ufe be received over it. It is not heavier than common air; and poffeffes the remarkable property of fuddenly uniting with vital air, with which it forms nitrous acid. The mixture of thefe two kinds of air forms a red cloud, which is imbibed by the water, and renders it acid, if the experiment be performed over that fluid; and, from examination of this acid water, it is proved that the cloud is the nitrous acid itfelf. From this circumftance Dr. Prieftley inftituted a method of determining the purity or refpirability of the air of the atmofphere, or any other permanently elaftic fluid. He found, by a variety of experiments, that when nitrous air and any other air are mixed, they undergo no change, if the latter be totally unfit to fupport combuftion or animal life; but, if the

Nitrous acid with combuftible matter.

Nitrous air, p. 94.

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

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the contrary, the red cloud is formed; and the whole bulk of the mixture is diminiſhed by a quantity which is ſo much the greater, accordingly as the air in queſtion is of a quality more ſuited to thoſe purpoſes. This diminution he likewiſe proved to conſiſt of a proportional part of the air which is tried, together with as much of the nitrous air as is required to produce the effect; ſo that, if the nitrous air be duly proportioned to the effect, it will wholly diſappear.

Imperfections of the trial of air by nitrous air.

The trial of the purity of common air by means of nitrous air, has not however been found to exhibit ſuch remarkable differences between the air taken up at various places as their known ſalubrity or unhealthineſs might have given reaſon to expect. Two reaſons may be offered to account for this. The firſt is, that a ſmall difference in the purity of the air of a place may have a very conſiderable effect on the health of thoſe who are obliged to breathe it for a long ſucceſſion of time: the ſecond is, that, the effects of nitrous air being the ſame upon elaſtic fluids which contain equal proportions of vital air, however greatly their other component parts may differ in their properties, it will only be ſhewn that the airs are equally ſalubrious, as far as depends on their proportion of vital air, though they may by no means be ſo with regard to their noxious parts.

Eudiometers.

There are ſeveral ingenious contrivances, called eudiometers, for the mixing of nitrous and other air, and meaſuring their diminution. As theſe however are not eaſily procured, and more eſpecially as Dr. Prieſtley, whoſe experience is greater than that of any other philoſopher, uſes a ſimple tube, it does not ſeem neceſ-

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neceſſary to deſcribe them here. The doctor's method is as follows:

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

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

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

When the preceding part of the proceſs is over, he transfers the air into a glaſs tube, about three feet long, and one third of an inch wide, carefully graduated according to the air meaſure, and divided into tenth and

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

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hundredth parts; fo that one of the hundredth parts will be about a fixth or an eighth of an inch. Then immerfing the tube in a trough of water, fo that the water in the infide of the tube fhall be on a level with the water on the outfide, he obferves the fpace occupied by the aerial mixture; and expreffes the refult in meafures and decimal parts of a meafure, according to the graduation of the tube.

Eudiometer tube.

It is fome trouble to graduate a tube in this manner; but when it is once done, the application of it is extremely eafy. As it feldom happens that a glafs tube is of an equal diameter throughout, the Doctor generally fills that part of the tube which contains one meafure with quickfilver; and then weighing it and dividing it into ten parts, he puts them in feparately, in order to mark the primary divifions. The weighing is rendered very eafy by the help of a glafs tube, drawn to a fine orifice, which ferves to take up a fmall quantity at a time, as may be required in making the adjuftment.

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It has been already obferved that common air lofes about one fourth of its bulk by any procefs equivalent to combuftion. This alfo happens when it is mixed with nitrous air.

Action of nitrous acid on animal fubftances.

When the nitrous acid acts upon the flefh, or other parts of animal fubftances, the elaftic fluid which is firft and moft plentifully difengaged is phlogifticated air. In this experiment the phlogifticated air may come from the animal fubftance, or the acid, or both; fince both contain it. It appears however to be much more probable that the whole comes from the animal fubftances; for it is afforded by the application of a

very

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very weak nitrous acid, at ſo low a temperature as 65° or 70°; both which circumſtances do not appear to indicate a decompoſition of the acid. The nitrous acid, after its action, ſaturates as large a quantity of alkali as before *. The quantity of phlogiſticated air is in proportion to the quantity of volatile alkali which the animal ſubſtance made uſe of affords by diſtillation: and it is known that the quantity of phlogiſticated air contained in any animal ſubſtance muſt be in this proportion. And, laſtly, at a greater heat, after the phlogiſticated air has come over, there is a diſengagement of nitrous air, which indicates a leſs complete decompoſition of the acid than that which would have afforded phlogiſticated air: and it is not conſonant with other chemical facts, that the complete decompoſition of the acid ſhould happen at a lower heat than the partial decompoſition which ſucceeds it.

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Various fluids imbibe nitrous air.

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

Diminution of nitrous air by electricity, &c.

The electric ſpark diminiſhes nitrous air about one

* The quantity of alkali ſaturated by any acid being different according to the ſtate of the acid, with regard to what is called phlogiſtication, this proof cannot be admitted as abſolutely concluſive, unleſs the ſame quantity of true nitre be formed in both caſes. I do not find whether this has or has not been done. See Annales de Chimie, I. 42.

 half,

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half, and converts it into phlogifticated air, at the fame time that acid is depofited. Iron filings and brimftone, liver of fulphur, or iron alone, being expofed to nitrous air, diminifh it, and convert it into phlogifticated air. But the moft fingular circumftance in thefe proceffes is, that, though they are of the nature of combuftion, and do in the end render air perfectly unfit for maintaining it, yet, at a certain period before this, the air is put into a ftate in which a candle burns in it better than in common air, though it ftill continues perfectly deftructive of animal life. Dr. Prieftley calls this dephlogifticated nitrous air.

Dephlogifticated nitrous air.

Abforption of nitrous air by the nitrous acid.

If nitrous acid be expofed to nitrous air, the latter is abforbed in large quantities; and the colour of the acid changes firft at the furface, and gradually through the whole of the liquid: the fucceffions of colour are, firft yellow, then deep orange, next green, and laftly blue, according to the quantities of nitrous air abforbed. This abforption renders the acid much more volatile. Hence it appears that the various colours of nitrous acid are owing to its having abforbed nitrous air, which continually efcaping, and combining with the vital air of the atmofphere, forms the yellow or reddifh fumes it ufually emits when in an open veffel.

Pale nitrous acid, becomes yellow:

The pale or dephlogifticated nitrous acid, if expofed to the action of light, gives out pure air, and itfelf becomes yellow and fuming. Heat alfo produces the fame effect. The nitrous acid itfelf appears to be capable of fubfifting in the aerial form, though its power of combining with water, mercury, or any other fluid ufed for confining it, prevents experiments from being made upon it with the fame facility as

— is capable of the elaftic form.

with

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with other kinds of air. Water impregnated with this air or vapour becomes ſucceſſively blue, green, and at laſt yellow, when it has received an increaſe of one third of its bulk. This water emits a great quantity of nitrous air, and does not ſeem to differ eſſentially from pure nitrous acid which has imbibed nitrous air.

Inflammation of eſſential oils by nitrous acid;

One of the earlieſt known facts of ſpontaneous inflammation is that produced by the affuſion of the nitrous acid upon oil. All the oils obtained by diſtillation from vegetables, and known by the name of eſſential oils, are proper for this experiment. An ounce of the oil intended to be ſet on fire muſt be placed in a ſhallow veſſel, and a bottle containing an ounce of the moſt concentrated nitrous acid muſt be faſtened at the end of a pole, that the operator may be ſufficiently diſtant from the inflammation. Two thirds of the acid being poured on the oil, makes a conſiderable ebullition; the oil growing black and thick, and ſometimes taking fire. But if this laſt circumſtance does not happen in five or ſix ſeconds, the remainder of the acid muſt be poured where the mixture appears moſt dry and black; and then the inflammation ſeldom fails to take place.

— of fat oils:

Fat oils may alſo be inflamed, if equal parts of the nitrous and vitriolic acids be firſt poured on them, and, when the ebullition is at the greateſt, a portion of nitrous acid be poured on the drieſt part.

—of charcoal, or lamp black.

Strong nitrous acid, of the ſpecific gravity of 1.54, being added to the powder of charcoal, or lamp black *, recently made very dry, takes fire, and detonates.

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

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nates. There is fome uncertainty in this experiment; but the method which is faid to enfure fuccefs, is, to put the dry powder into a very dry retort, and pour the acid upon the fide of the glafs, fo that it may not fall upon the powder, but flow beneath it.

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

Recapitulation and theory.

On a review of the facts in the foregoing chapter, it will not be difficult to apply in a general way the fame theories as were exhibited in treating of the vitriolic acid. The preparation of nitre beds confifts fimply in a procefs by which the exhalations of putrid fubftances may combine with vital air, and the product be received into a combination with calcareous earth, or with the alkali of decayed vegetables; and the fubfequent manipulations are the mere application of water, to feparate the feveral matters from each other according to their refpective degrees of folubility. That nitrous acid contains vital air, is evident from the diftillation of nitre without addition; and that in the acid it is applied to, or combined with, phlogifticated air, appears equally clear from the * experiment of Mr. Cavendifh, and from the frequent appearance of this aerial fubftance in experiments with nitrous air. The queftion in this procefs therefore feems to be, whether the air called phlogifticated air do really

* Phil. Tranf, quoted, page 152.

contain

contain an inflammable principle, which it gives out during combination with the vital air; or whether it simply unite to this laſt? Upon the former ſuppoſition, the theory of the general facts will be as follows: NITROUS ACID.

Nitrous acid conſiſts of vital air united to a certain proportion of phlogiſticated air, which has been deprived of phlogiſton during combination. When a combuſtible body is preſented to this acid, it becomes corroded or burned; that is to ſay, it combines with ſome of the vital air, and parts with ſome of its own phlogiſton. In this ſtate the acid is no longer the ſame; for it has loſt vital air, and part of its phlogiſticated air has regained phlogiſton. It therefore emits either nitrous air, which is an imperfect nitrous acid, wherein the phlogiſton is too abundant, and the vital air too deficient, to exhibit acid properties; which on that account readily abſorbs vital air, and is by that means precipitated again in the original acid form: or, if the decompoſition be more completely made, the quantity of vital air abſorbed, and of phlogiſton emitted, by the combuſtible body, may be ſuch as that only phlogiſticated air ſhall be extricated, as is the caſe with animal ſubſtances. Again, the compoſition of nitrous air being thus eſtabliſhed, if the electric ſpark be applied to produce ignition in this aerial fluid, the ſmall portion of vital air intimately unites with as much of the phlogiſticated air as is required to form nitrous acid, and leaves the reſidue of phlogiſticated air behind: or, if any proceſs of ſlow combuſtion be carried on in it, the whole of the vital air is abſorbed, and as much phlogiſton extricated as converts the reſidue into phlogiſticated air. It is evident that the

Theory.

Page 159.

Page 162.

Page 163.

Ibid.

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 abſorp-

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absorption of nitrous air must equally alter the proportions of the component parts of the nitrous acid, and produce similar effects.

The singular properties of the air called dephlogisticated nitrous air have not been satisfactorily explained upon any theory.

Theory:

— of the antiphlogistians.

It is obvious that the explanation of these events may be made at least with equal facility according to the other theory. Phlogisticated air and vital air are applied to each other under certain circumstances, and nitrous acid is produced. Hence it is concluded that these aerial substances have united together, and are the component parts of nitrous acid. When an inflammable substance is burned, or a metal calcined, by the action of this acid, one of its component parts, namely, vital air, unites with the body; and the surplus of the other principle, namely, phlogisticated air, flies off either alone, or in combination with a sufficient portion of vital air to form nitrous air. The addition of vital air to this last aerial product completely forms nitrous acid; the subtraction of the vital air it possesses must change it into phlogisticated air.

Action of light.

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

 liberty.

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Theory.

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

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

Keir's compound acid. See Chap. II. Book II.

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

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

* Phil. Tranſ. Vol. LXXX. p. 373.

CHAP. III.

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

COMMON SALT.

Salt mines and springs.

THE marine acid is obtained from common culinary salt, in which it is united to the mineral alkali. Common salt is found in large masses, or in rocks, under the earth, in England and elsewhere. There are also many salt springs in various parts of the world; and the waters of the ocean every where abound with it, though in different proportions. The water of the Baltic sea * is said to contain one sixty-fourth of its weight of salt; that of the sea between England and Flanders contains one thirty-second part; that on the coasts of Spain one sixteenth part; and between the tropics it is said, perhaps erroneously, to contain from one eleventh to one eighth part.

Sea water.

Extraction of common salt from waters.

The whole art of extracting salt from waters which contain it, consists in evaporating the water in the cheapest and most convenient manner. In England, a brine composed of sea water, with the addition of rock salt, is evaporated in large shallow iron boilers; and the crystals of salt are taken out in baskets. In Russia, and probably in other northern countries, the sea water is exposed to freeze; and the ice, which is almost entirely fresh, being taken out, the remaining brine is much stronger, and is evaporated by boil-

* Rome de l'Isle's Crystallographie, Vol. I. p. 375, quoted by Magellan in his improved edition of Cronstedt, p. 360.

ing.

COMMON SALT.

ſing. In the ſouthern parts of Europe the ſalt-makers take advantage of ſpontaneous evaporation. A flat piece of ground near the ſea is choſen, and banked round, to prevent its being overflowed at high water. The ſpace within the banks is divided by low walls into ſeveral compartments, which ſucceſſively communicate with each other. At flood tide, the firſt of theſe is filled with ſea water; which, by remaining a certain time, depoſits its impurities, and loſes part of its aqueous fluid. The reſidue is then ſuffered to run into the next compartment; and the former is again filled as before. From the ſecond compartment, after a due time, the water is transferred into a third, which is lined with clay, well rammed, and levelled. At this period the evaporation is uſually brought to that degree, that a cruſt of ſalt is formed on the ſurface of the water, which the workmen break, and it immediately falls to the bottom. They continue to do this until the quantity is ſufficient to be raked out, and dried in heaps. This is called bay ſalt.

Various methods —of obtaining ſalt. — from the waters

In ſome parts of France, and alſo on the coaſts of China, they waſh the dried ſands of the ſea with a ſmall proportion of water, and evaporate this brine in leaden boilers.

— of the ſea

At ſeveral places in Germany, and at Montmarot in France, the waters of ſalt ſprings are pumped up to a large reſervoir at the top of a building or ſhed; from which it drops or trickles through ſmall apertures upon boards covered with bruſh wood. The large ſurface of the water thus expoſed to the air, cauſes a very conſiderable evaporation; and the brine is afterwards conveyed

— and ſalt ſprings.

COMMON SALT.

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

Salts contained in the fea.

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

Cryftallization of common falt.

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

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

efcape

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escape of its water of cryſtallization. A greater heat ignites and melts it; and a ſtill greater cauſes it to riſe totally in white fumes. The action of ſea ſalt upon earths is not conſiderable. It aſſiſts the fuſion of ſiliceous earth; and is thrown into the furnace wherein the pottery called ſtone-ware is baked, where it riſes in fumes, and glazes their ſurface; probably by the combination of its alkali with the ſiliceous earth contained in the clay. The decompoſition of ſea ſalt by litharge has already been mentioned in treating of the mineral alkali. Page 118.

Diſtillation of marine acid from common ſalt.

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

Marine acid air.

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Diftillation.

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

Marine acid air:

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

— its corrofive nature.

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

Salt of Sylvius.

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

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its weight of water. This is ſometimes uſed in medicine.

Sal ammoniac.

With the volatile alkali it forms common ſal ammoniac, which is a conſiſtent ſalt, of a ſharp briny taſte; and ſo remarkably deficient in the uſual brittleneſs of this claſs of bodies, that it is not eaſily pulverized. It is ſoluble in between three and four times its weight of water, in a common temperature. By heat it ſublimes entire in cloſed veſſels.

Marine ſelenite.

The ſaline combination of lime with marine acid is ſometimes called marine ſelenite, and ſometimes fixed ammoniac; becauſe it forms the fixed reſidue after ſal ammoniac has been expoſed to diſtillation with lime. This ſalt may be obtained in the form of cryſtals, but it deliqueſces with air. It is ſoluble in leſs than twice its weight of cold water. The combination of lime and marine acid which remains after diſtilling ſal ammoniac, has uſually an over-proportion of lime. If it be urged by a violent heat, it fuſes; and when cold, it has the property of emitting a phoſphoric light upon being ſtruck with any hard body. Hence it is called Homberg's phoſphorus, from the name of the firſt obſerver.

Homberg's phoſphorus.

Argillaceous marine ſalt.

The argillaceous marine ſalt has a gelatinous conſiſtence when diſſolved in a ſmall quantity of water. Its taſte is ſtyptic, and it affords cryſtals by ſpontaneous evaporation.

Ponderous marine ſalt.

The combination of ponderous earth with marine acid forms a cryſtallizable ſalt of difficult ſolution. Its ſolution is of admirable uſe for detecting the preſence of the vitriolic acid in any fluid; becauſe this air combines with the earth, and forms an inſoluble precipitate of ponderous fpar. It is more efpecially ufeful for purifying the marine acid itfelf from the vitriolic acid, which it often contains. The exact quantity of folution neceffary to be added for this purpofe to any veffel of marine acid, may be known by previous trials with fmall portions of the acid.

Magnefian marine falt.

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

Action of marine acid upon metals.

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

Dephlogifticated or aerated marine acid.

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

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

the

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

Dephlogifticated or aerated marine acid.

Annales de Chimie, II. 151—190.

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

Salt into which dephlogifticated marine acid enters.

 than

MARINE ACID.

Detonating marine falt; with bafe of vegetable alkali:

than in cold water, affords cryftals by cooling. Thefe are of a long rhomboidal figure, and a filvery brilliancy; have an infipid cooling tafte, refembling nitre; do not deliquefce in the air; and detonate with charcoal, or with iron, more ftrongly than nitre itfelf does. By heat alone they give out vital air; and the refidue of their detonation with charcoal is the falt of Sylvius. Hence it is obvious that a portion of the alkali has imbibed fome of the dephlogifticated marine acid, together with the overplus of vital air contained in a great part of the reft of the acid; and that this alkali forms the prefent falt; while the acid which was deprived of the overplus, and by that means reduced to the common ftate, forms the falt of Sylvius, which is in much the greateft proportion in the folution.

— with mineral alkali:

If the mineral alkali be ufed, a falt nearly of the fame nature is formed; but too deliquefcent to afford cryftals.

—volatile alkali.

Volatile alkali is decompofed by the dephlogifticated marine acid; the vital air combining with its inflammable part, and the phlogifticated air flying off.

Action of light.

When the folution of dephlogifticated marine acid is expofed to the action of light, it emits vital air, and becomes converted into common marine acid.

Theory.

When we reafon by analogy from the vitriolic and nitrous to the marine acids, we muft conclude that this laft confifts of a bafe of a combuftible nature united to vital air. And as the greater combuftibility of fulphur, the bafe of the vitriolic acid, when compared with phlogifticated air, or the bafe of nitrous acid, appears to be the caufe why the action of the latter is more generally effectual upon combuftible bodies,

MARINE ACID.

Theory.

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

Action on combuftible bodies.

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

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

 acid.

AQUA REGIA.

Theory.

acid. From this inftance acidity appears to have its limits, fo as to confift of a precife term of dephlogiftication, or of faturation with vital air; and to be impaired or deftroyed by an excefs either way. A full and adequate explanation of the changes of the marine acid cannot but afford much advantage to the general theory of acids, which occupy fo large a fpace among the objects of chemical inquiry.

Compofition of aqua regia:

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

—otherwife.

Aqua regia may be made by adding to nitrous acid any falt which contains the marine acid: for the affinity of the nitrous acid to the bafe being in moft cafes ftronger than that of the marine, this laft is fet at liberty; and confequently the mixture, if the falt be not exceffive in quantity, will contain the acids in a difengaged ftate. An aqua regia will therefore be produced, which is not effentially impaired with refpect to common ufes by the portion of falt it may hold in folution. It is ufual to make aqua regia by diffolving fal ammoniac in about four times its weight of ftrong nitrous acid; but the refults

* Berthollet, in Acad. Par. 1785.

of

AQUA REGIA.

of experiments or operations muſt vary conſiderably according to the proportion and the ingredients made uſe of.

The effects and theory of aqua regia.

The nature of this mixed acid has not yet been clearly aſcertained. After the diſcovery of the dephlogiſticated marine acid, it was concluded, that the nitrous acid performed the ſame office as the manganeſe does; that is, in fact, that it either deprives the marine acid of phlogiſton, or affords vital air to combine with it, or both. Several difficulties however oppoſe this ſuppoſition. If the marine acid be enabled to calcine and diſſolve gold becauſe it has been dephlogiſticated or aerated by the nitrous acid, it ſhould follow much more ſtrongly that the nitrous acid itſelf ſhould diſſolve that metal, which is contrary to the fact. And, again, it has not been ſhewn how this dephlogiſticated acid, which is ſo volatile, and ſo ſparingly ſoluble in water, is retained in the ſolution: not to mention that no component part of the nitrous acid is found to eſcape during the efferveſcence, except the vital air which enters into the compoſition of the gas that flies off. When the two acids are in due proportion, therefore, aqua regia muſt conſiſt of marine acid, and nitrous acid which has an under-proportion of vital air, or is in the moſt fuming ſtate; or, in other words, it contains the two baſes of the acids, together with vital air, leſs in quantity than they poſſeſſed in their ſeparated ſtate. But, whether theſe principles combine and form a compound acid, or in what other order they may be arranged, has not yet been experimentally determined; though the writings of chemiſts abound with conjectural inferences reſpecting them.

 The

AQUA REGIA. Combinations.

The combinations of earths and alkalis, and even of metals, with aqua regia, have not been well examined. It is not known whether two different kinds of ſalts are formed apart from each other, or whether a triple combination takes place conſiſting of two acids united to one baſe. It appears however that in ſome caſes the reſult is one entire compound, and in others two ſeparate ones.

CHAP.

CHAP. IV.

OF FIXED AIR, FIXABLE AIR, OR AERIAL ACID.

FIXED AIR.

THE acid which is commonly known by the name of fixed air, abounds in great quantities in nature, and appears to be produced in a variety of circumstances. It composes about one third of the weight of limestone, marble, calcareous spar, and other natural specimens of calcareous earth, from which it may be extricated either by the simple application of heat, or by the superior affinity of some other acid; most acids having a stronger action on bodies than this. This last process has been before described. It does not require heat, because fixed air is strongly disposed to assume the elastic state. Water, under the common pressure of the atmosphere, and at a low temperature, absorbs somewhat more than its bulk of fixed air, and then constitutes a weak acid. If the pressure be greater, the absorption is augmented. Heated water absorbs less; and if water impregnated with this acid be exposed on a brisk fire, the rapid escape of the aerial bubbles affords the appearance of the water being at the point of boiling, when the heat is not greater than the hand can bear. Congelation separates it readily and completely from water; but no degree of cold or pressure has yet exhibited this acid in a dense or concentrated state of fluidity.

Substances which contain fixed air.

Page 52—55.

Impregnation of water.

Fixed air is nearly twice as heavy as common air; and for that reason occupies the lower parts of such

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

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

Fixed air emitted from fermenting bodies. Fixed air is emitted in large quantities by bodies in the ftate of the vinous fermentation; and on account of its great weight it does not fly off, but remains in the upper fpace of the veffel, not occupied by the fermenting body. A variety of ftriking experiments may be made

Experiments made in an atmofphere of fixed air. in this ftratum of elaftic fluid. Lighted paper or a candle dipped into it, is immediately extinguifhed; and the fmoke remaining in the fixed air renders its furface vifible, which may be thrown into waves by agitation, like water. If a difh of water be immerfed in this air, and brifkly agitated, it foon becomes impregnated, and obtains the lively tafte of Pyrmont water. In confequence of the weight of the fixed air, it may be dipped out in a pitcher, or bottle; which, if well corked, may be ufed to convey it to great diftances. The effects produced by pouring this invifible fluid from one veffel to another, have a very fingular appearance: if a candle, or a fmall animal, be placed in a deep veffel, the former becomes extinct, and the latter expires, in a few feconds after the fixed air is poured upon them, though the eye is incapable of diftinguifhing any thing that is poured.

When

FIXED AIR.

When vegetable ſubſtances are expoſed to a ſtrong heat in veſſels partly cloſed, the volatile principles fly ɔff; but combuſtion does not take place for want of ıir. The fixed reſidue is the inflammable ſubſtance :alled charcoal. For general purpoſes, wood is con- 'erted into charcoal by building it up in a pyra- nidical form, and covering the pile with clay or earth, eaving a few air-holes, which are cloſed when the naſs is perfectly lighted; and by that means the com- uſtion is carried on in an imperfect manner. Com- ıon charcoal, when expoſed to heat in cloſed veſſels, ives out a ſmall quantity of inflammable air, which :ems extraneous to it; and if it be burned, it leaves ſmall portion of earth, fixed alkali, and other ſalts. 'he greater part of charcoal therefore conſiſts of an ıflammable ſubſtance; and it is found that, if this be urned in a cloſed veſſel over mercury, with vital air, ıe product is fixed air, and nothing elſe; as is proved y the reſidue after the fixed air has been abſorbed by ıuſtic fixed alkali: for there is either no aerial reſi- ıe, or the reſidue conſiſts of vital air as pure as at rſt *.

Converſion of vegetable matter into charcoal.

Production of fixed air from charcoal.

Hence it follows, that fixed air conſiſts of the in- ımmable matter of charcoal united to vital air. The ıtiphlogiſtian philoſophers conſider this matter as a :culiar combuſtible and acidifiable baſe, and thence fer the preſence of charcoal in all caſes where fixed r is extricated or produced: but, on the other hand, veral of the phlogiſtians think themſelves juſtifiable concluding that fixed air is produced by the union

Compoſition of fixed air.

Opinions.

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

of

FIXED AIR.

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

The electric fpark paffed through fixed air.

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

Phlogiftic explanation.

Antiphlogiftic explanation.

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

the

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

Combinations of fixed air; with clay:

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

—with calcareous earth:

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

—with ponderous earth:

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

— with magnefia.

Magnefia unites readily to a large proportion of fixed air.

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

an

FIXED AIR.

Cryftallized combination of magnefia with fixed air.

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

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

This

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

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

Fixed air has no action upon ſiliceous earth.

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

Alkaline

FIXED AIR.

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

Combination of fixed air with combuftible matter.

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

Advantages derived from a knowledge of this acid.

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

CHAP.

CHAP. V.

OF THE ACID OF BORAX.

BORAX.

BORAX is a ſalt which comes to us from the Eaſt Indies, and whoſe origin has till lately been ery dubious. At preſent however it is very well ſcertained * that it is dug up in a cryſtallized ſtate om the bottom of certain ſalt lakes in a mountainus, barren, volcanic diſtrict, about five-and-twenty ys journey to the eaſtward of Laſſa, the capital of e kingdom of Thibet. Tincal, or crude borax, the ſtate we receive it, is of a dull white or eeniſh colour, in irregular cryſtals, covered with rancid oily ſubſtance, ſaid to be added to prevent deliqueſcing, and intermixed with earthy impuri- es. It is not well known in what proportions the mponent parts exiſt in the borax when dug out of e earth; becauſe it is ſaid to be purified by ſubſe- ent ſolution in water and cryſtallization ſoon after comes from the mountains: and the borax of mmerce is chiefly refined in Holland by a proceſs hich is kept a ſecret; though there is little doubt it it conſiſts of ſolution, filtration, cryſtallization, d calcination, to free it from the impurities and eaſe; and afterwards a ſecond ſolution and cryſtal- zation, probably with an addition of mineral alkali, ſalt of ſoda. M. Chaptal, after trying various

Natural production of tincal or crude borax.

Purification of borax.

* Phil. Tranſ. Vol. LXXVII. No. 21. 29.

BORAX AND ITS ACID.

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

Analysis of borax.

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

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

Habitudes of borax:

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

* Elements of Chemistry, Eng. Translation, I. 277.

may

BORAX AND ITS ACID.

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

— and its acid.

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

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

Native acid of borax.

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

Hard cryftallized ftone containing acid of borax.

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

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

BORAX AND ITS ACID.

Analyſis of the native combination of the acid of borax with lime and magneſia.

ſome are ſemi-tranſparent, and a few are perfectly tranſparent. The greater number of theſe cryſtals have the appearance of having been corroded. It is evidently of a laminated texture; though its fracture ſeems to exhibit a radiated appearance. Its ſpecific gravity is about 2.566, and its hardneſs is ſuch that it ſcratches glaſs, and gives fire plentifully with the ſteel.

This ſtone loſes its tranſparence by ignition, and becomes pulverable if quenched in water; though the hardneſs of its particles cauſes it to abrade the hardeſt mortars which can be uſed. An extreme degree of heat cauſes it to run into a yellow glaſs. Water does not diſſolve it, either cold or by ebullition. Alkalis act upon it in the dry way, but not readily; and in this operation a conſiderable loſs of weight is experienced. Acids, by long boiling upon the pulverized ſtone, diſſolve it for the moſt part. Five days boiling of marine acid upon one hundred grains of the ſtone diſſolved it at laſt.

The ſolution in marine acid firſt exhibited foliated cryſtals at its ſurface, which fell to the bottom; and as the evaporation proceeded, the whole maſs fixed into a yellowiſh white ſubſtance. This was ſoluble in water, and let fall a ſmall portion of ſiliceous earth. The ſolution, being examined by the methods of analyſis hereafter to be deſcribed, afforded a ſmall quantity of iron, with ſome lime; and, by the addition of vitriolic acid and ſublimation, the acid of borax was obtained. An additional quantity of this ſubſtance was afforded by waſhing the reſidue with the ſtrongeſt ardent ſpirit, and evaporating the ſolution till cryſtals were afforded. The component parts of the ſtone were thus found to be be—Acid of borax deprived of its water of cryſtallization by a red heat, 68 parts; magneſia, $13\frac{1}{2}$; lime, 11; clay, 1; calx of iron, 1; ſilex, 2; loſs in the operation, $3\frac{1}{2}$. By adding the mineral alkali to the acid thus obtained, a true borax was formed.

BORAX AND ITS ACID.

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

Combinations of the acid of borax with earths and alkalis.

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

Suppoſed reduction of borax.

* Ruprecht in the Journal de Phyſique for 1790.

CHAP. VI.

OF THE ACID OF SPAR.

ACID OF SPAR.

Fluor or Derbyshire ſpar.

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

Diſtillation of the acid.

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

Diſtinctive character.

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

ACID OF SPAR.

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

Siliceous earth diffolved.

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

Etchings on glafs.

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

Combinations with earths and alkalis:

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

—with metals.

CHAP. VII.

OF THE ACID OF AMBER.

AMBER.

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

Characters of amber:

— where found.

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

in

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

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

Combinations of the acid of amber.

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

CHAP. VIII.

OF PHOSPHORUS AND ITS ACID.

PHOSPHORIC ACID.

Native phofphorus.

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

Characters of phofphorus.

Page 140.

* Annales de Chimie, I. 196.

This

PHOSPHORUS.

This ſubſtance, remarkable for its extreme combuſtibility, and the exhibition of flame without heat, was firſt diſcovered about the year 1667, by a chemiſt whoſe name was Brandt. Another chemiſt, well known by his writings, whoſe name was Kunckel, diſcovered the ſecret of Brandt by a ſet of experiments expreſsly inſtituted for that purpoſe. It is to this philoſopher that the world has juſtly given the honour of the diſcovery. Our eminent Robert Boyle likewiſe made the diſcovery upon the ſame information probably as that of Kunckel; namely, that the phoſphorus was produced from urine. It is aſſerted that a certain dealer in ſecrets, one Krafft, communicated the proceſs to Boyle *; but it is not probable that a man of ſuch undoubted integrity as Boyle would have communicated the proceſs to the Royal Society as his own, if this had been the caſe. Neither indeed does the invention appear to be of that magnitude, as not to be eaſily hit upon by thoſe who were determined to ſpare no pains nor attention in the purſuit of diſcovery, as was the caſe with the chemiſts of that day, moſt of whom indulged extravagant hopes. The proceſs of Boyle conſiſted in nothing more than diſtilling urine till the laſt volatile product came over, which is the phoſphorus; and he uſed no other artifice to facilitate the operation, than that of firſt evaporating the fluid part of the urine until it became of the conſiſtence of ſyrup. He then mixed this liquid with thrice its weight of fine ſand, and expoſed the whole to diſtillation for

The diſcovery of phoſphorus; by Brandt, Kunckel, and Boyle.

Defence of Boyle as the inventor.

Proceſs of Boyle.

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

twelve

PHOSPHORUS.

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

Proceſs for obtaining phoſphorus from bones.

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

Phoſphoric glaſs.

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

bottom.

PHOSPHORUS.

Procefs for obtaining phofphorus.

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

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Purification of phofphorus.

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

PHOSPHORIC ACID.

Purification of phoſphorus.

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

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

Phoſphoric acid, obtained by ſlow combuſtion.

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

Concrete phoſphoric acid.

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

Page 202.

* Annales de Chimie, I. 234.

it

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

PHOSPHORIC ACID.

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

Phosphoric acid; obtained by the action of nitrous acid:

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

— by vitriolic acid:

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

— by strong combustion:

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

— by a stream of vital air.

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

Phosphoric hepar; and air.

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PHOSPHORIC ACID.

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

Combination of phofphorus with fulphur:

Sulphur and phofphorus unite by fufion, and form a folid compound of a fetid fmell, which burns with a yellow flame, and fwells in water; at the fame time communicating acidity to that fluid, and emitting a fmell of hepatic air.

— with oils:

All kinds of oils diffolve phofphorus, and are rendered luminous by it: feveral effential oils form a folution which takes fire by expofure to the air, probably in confequence of the emiffion of phofphoric air. The butter of wax, which confifts of wax deprived of part of its acid by diftillation, is faid to be the propereft material for producing this effect.

—ardent fpirits:

Very ftrong ardent fpirit diffolves a fmall portion of phofphorus, which gives a perceptible light upon the addition of water.

— metals.

Metals do not readily combine with this fubftance when fimply heated with it: but when the phofphoric acid, together with charcoal, is expofed to a ftrong heat, a confiderable number of the metals may be made to unite with it *, probably in confequence of their being previoufly calcined by the acid.

Metals revived by phofphorus.

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

Ufes of phofphorus.

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

* Journal de Phyfique, for March 1789.

writing

writing made of a ſtick of phoſphorus upon paper, or any other ſubſtance which can abrade it, is ſufficiently known. There is ſome danger of its catching fire if the friction be ſwift or violent; and for that reaſon the ſtick of phoſphorus ought to be held in a metallic caſe, and a cup of water ſhould be at hand to plunge it in. It is alſo uſed when diſſolved in eſſential oils, or butter of wax, to make tapers or matches, intended to ſupply the place of flint and ſteel in producing light; but it is not probable that theſe will ever be afforded ſufficiently cheap to anſwer the purpoſe of a ſubſtitute to that operation.

Phoſphoric matches.

The acid of phoſphorus exiſts, as has been already obſerved, in two ſtates ſimilar to thoſe of the volatile and fixed vitriolic acids: and the difference between theſe ſtates ariſes likewiſe from a ſimilar cauſe; namely, that a part of the phoſphorus is not converted into acid, but is held in ſolution by that part which is acidified. Neither of the kinds of phoſphoric acid riſes totally by heat like the volatile vitriolic acid: but that which contains phoſphorus emits white fumes, which ſeem to conſiſt of part of the acid combined with the redundant phoſphorus; and the reſidue melts into the vitreous form. This difference between the vitriolic and phoſphoric acids depends no doubt upon the greater degree of fixity of the latter.

Two ſtates of phoſphoric acid.

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The phoſphoric acid does not appear to act upon ſiliceous earth, though it corrodes glaſs when hot. It unites with clay in the dry way. With calcareous earth it forms a combination ſcarcely ſoluble in water, unleſs there be an exceſs of acid: it has been already noticed that the earthy reſidue of bones conſiſts of

Combinations of phoſphoric acid.

this

PHOSPHORIC ACID.

this fubftance. With ponderous earth it forms a falt whofe properties are little known; and with magnefia it forms a cryftallizable compound of difficult folubility.

Combinations of phofphoric acid with alkalis.

This acid, when in combination with the vegetable alkali, forms a very foluble falt, which is fufpended in confiderably greater quantity in hot than in cold water. It feparates from the liquid in cryftals, either by cooling or evaporation. The combination of phofphoric acid with mineral alkali conftitutes a falt of an agreeable tafte, refembling that of common falt. It is not eafily cryftallized, by reafon of its difpofition to form an adhefive matter by evaporation, which refembles gum. A fmall excefs of alkali renders it more difpofed to cryftallize, and caufes it to efflorefce by expofure to the air. This falt has been lately introduced into medicine. The combination of volatile alkali with phofphoric acid is likewife more foluble in hot than in cold water, and affords cryftals by cooling. An excefs of alkali renders the cryftallization more eafy. It is greatly difpofed to fly off by a gentle heat.

Phofphoric falts from urine.

The phofphoric falts were firft obtained from urine. This animal fluid confifts of a large quantity of water; the acids of phofphorus and of the calculus of the bladder, both in a difengaged ftate; fome common falt, with the faline combinations of the phofphoric acid with lime, mineral alkali, and volatile alkali; and two kinds of extractive matter, one of which is foluble in ardent fpirit, and the other in water. When urine is expofed to evaporation by heat, it affumes a darker colour; and a pulverulent matter falls down, which

PHOSPHORIC ACID.

which consists of the calcareous phosphoric salt, and the acid of the human calculus. If the urine be filtered as soon as it has acquired a viscid consistence, it affords saline crystals by cooling. These consist of the common salt, and also of a triple combination of phosphoric acid with the mineral and vegetable alkalis, which is generally known by the name of microcosmic salt. Repeated evaporations and coolings are required to deprive urine of the most part of its salts. Subsequent solution in water, heated and cooled in closed vessels, purifies the phosphoric crystals, and separates the salt with the base of volatile alkali from that which contains mineral alkali. As the former of these salts only is decomposed by heating with charcoal, it is from this alone that the phosphorus of urine is obtained. The combination of mineral alkali with phosphoric acid was for some time supposed to be a peculiar acid, and was called the perlate acid.

Salts from urine.

Microcosmic salt.

Perlate acid.

The microcosmic salt has been applied to great use by the celebrated Bergman, as a flux in blow-pipe experiments.

Phosphoric acid unites with several of the metallic calces. It acts upon oils, to some of which it communicates a peculiar flavour, and it thickens others. It has not been well decided whether it can be exhibited in the elastic state at the temperature of the atmosphere.

Combinations of phosphoric acid with metals and oils.

The saline compounds formed by the phosphoric acid, when not totally acidified, appear to differ from those of the complete acid; but few experiments have been made with these.

The theory of the conversion of phosphorus into

Theory.

PHOSPHORIC ACID.

Theory.

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

CHAP. IX.

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

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

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

 the

METALLIC ACIDS. Acidification of metals.

the action of acids, as by heating them with accefs of pure air. When they are thus calcined they become foluble in acids. Some of the metallic bodies have been difcovered to be fufceptible of a farther continuation of the procefs by which they are calcined; and this continuation is found to change them into acids foluble in water, and difpofed to combine with and neutralize alkaline fubftances. Hence there feem to be certain periods of combuftion at which the fame fimple bafis becomes fucceffively converted into a calx, or fubftance capable of neutralizing acids; and afterwards into one which combines with and neutralizes alkalis. If we might generalize this, it would be fair to conclude that all metals are, in their own nature, capable of being converted into acids; that all acids are reducible to inflammable fubftances, though art has not yet devifed the means of doing it in every inftance; and it might be conjectured that the fixed alkalis themfelves may confift of combinations of inflammable fubftances with pure air, to which they may adhere with too ftrong an affinity to be feparated by means of any medium we are acquainted with.

General inferences; by conjecture.

Metals acidified.

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

Arfenic.

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

METALLIC ACIDS.

Proceſs for obtaining the arſenical acid.

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

Characters of arſenical acid.

Combinations with earths:

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

—with alkalis.

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

METALLIC ACIDS.

Reduction of arsenical acid.

limes. When the fluid acid is digested with charcoal powder, no change takes place until the moisture is evaporated; and when the heat is raised to ignition, a sudden combustion takes place, all the acid is reduced and sublimed into the neck of the retort, the greater part being in the form of the metallic regulus, and the rest calx. Continued digestion with oils revives this acid. It unites with sulphur by fusion, the whole mass rising almost instantly in the form of a red sublimate, at the same time that volatile sulphureous acid passes into the receiver.

Combination with sulphur.

Theory.

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

of

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

Characters of molybdena.

Molybdena is a ſubſtance which greatly reſembles plumbago, or black lead; but its texture is ſcaly, and it is not eaſily pulveriſed, on account of a degree of flexibility which its laminæ poſſeſs. If it be triturated in a mortar with vitriolated tartar, this ſaline ſubſtance will, by the hardneſs and angular figure of its particles, render it more eaſily pulverable; and when this purpoſe is accompliſhed, the ſalt may be waſhed away by ſeveral affuſions of water. If the powder be then placed in a retort, with five or ſix times its weight of diluted nitrous acid, and diſtillation be carried on to dryneſs, it is found that volatile vitriolic acid and nitrous air are extricated, and the colour of the reſidue becomes lighter. More acid muſt then be added, and the diſtillation again repeated till the fourth or fifth time. A ſtrong heat is required to drive off the laſt portions of vitriolic acid formed by the ſulphur. When no more red vapours appear, the reſidue will be white and pulverulent, reſembling chalk. This is the acid of molybdena. It requires near five hundred times its weight of boiling water to diſſolve it, and exhibits weak acid properties.

Proceſs for obtaining the acid of molybdena.

Combinations.

This acid combines with lime, magneſia, and calcareous earth, with which it forms ſalts of very difficult ſolution. When added to a ſolution of ponderous earth in the nitrous or marine acids, it forms a compound which is ſparingly ſoluble in cold water; and, on that account, falls to the bottom. The combi-

METALLIC ACIDS.

nation of this acid with vegetable alkali is more ſoluble in water than the acid itſelf, and affords cryſtals by evaporation. It unites likewiſe with the volatile alkali. Several of the metals, when diſſolved, are likewiſe ſeized by this acid, and precipitated from their ſolutions.

Regenerated molybdena.

When the acid of molybdena is heated with ſulphur in a retort, placed in ſuch a manner as that the ſublimed ſulphur may melt and run back again, a combination between theſe two ſubſtances is at length produced; and the ſuperfluous ſulphur flies off, being partly converted into volatile vitriolic acid. The reſidue is found to be in every reſpect the ſame as the native molybdena. The analyſis of molybdena by the nitrous acid ſhewed that it conſiſts of ſulphur united to a peculiar acid, or acid baſis; and this ſynthetical production of molybdena proves the ſame thing.

Acid of tungſten, or wolfram.

The acid of tungſten, or wolfram, is a peculiar metallic ſubſtance obtained from theſe minerals. The tungſten is a ponderous ore, of a grey colour, and lamellar texture. It conſiſts of the metallic calx, or acid, united to about its own weight of calcareous earth. Wolfram is a mineral of ſtill greater ſpecific gravity, which is formed in the tin mines of Cornwall, and elſewhere. It is of a browniſh black colour, of a radiated or foliated texture, internally ſhining almoſt with the luſtre of a metal. It is of a moderate hardneſs, though ſometimes ſo friable as to be pulverable between the fingers. It contains about two-thirds of the peculiar calx or acid; and the

Procefs for obtaining the acid of tungften, or wolfram.

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

* Scheele.

The

METALLIC ACIDS.

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

Procefs for obtaining the acid of tungften, or wolfram.

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

Characters of the acid.

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

It

METALLIC ACIDS.

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

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

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

BOOK

BOOK II.

PARTICULAR CHEMISTRY.

SECTION III.

OF METALLIC BODIES.

CHAP. I.

CONCERNING GOLD.

GOLD. Characters of gold.

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

GOLD.

Obvious properties.

that commotion through gold leaf between two plates of glafs; or by caufing the explofive fpark of three or more fquare feet of coated glafs to fall upon a gilded furface. A ftrong heat is required to melt it, which does not happen till after ignition. Its colour when melted is of a blueifh green; and the fame colour is exhibited by light tranfmitted through gold leaf.

Extreme ductility and tenacity.

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

Manufacture of gold leaf:

The method of extending gold, ufed by the gold-beaters, confifts in hammering a number of thin rolled plates between fkins or animal membranes. By the weight and meafure of the beft wrought gold leaf, it is found that one grain is made to cover $56\frac{3}{4}$ fquare inches; and from the fpecific gravity of the metal, together with this admeafurement, it follows, that

— its thicknefs.

the leaf itfelf is $\frac{1}{282000}$ part of an inch thick. This however is not the limit of the malleability of gold; for the gold-beaters find it neceffary to add three grains of copper in the ounce to harden the gold, which otherwife would pafs round the irregularities of the neweft fkins, and not over them; and in ufing the old fkins, which are not fo perfect and fmooth, they proceed fo far as to add twelve grains. The

Gilt wire.

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

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

Solvents.

No acid acts readily upon gold but aqua regia and the dephlogifticated marine acid. The vitriolic acid diftilled from manganefe has fome action upon it; as have likewife the pale nitrous acid, and the phofphoric acid when boiling.

Aqua regia.

The fmall degree of concentration which the dephlogifticated marine acid is fufceptible of, and the imperfect action of the latter acids, render aqua regia the moft convenient folvent for this metal.

Solution of gold.

When gold is immerfed in aqua regia, an effervefcence takes place with the efcape of air, which has not been examined; the folution tinges animal matters of a deep purple, and corrodes them. By careful evaporation, fine cryftals of a topaz colour are obtained.

Precipitates: — by earths and alkalis:

The gold is precipitated from its folvent by a great number of fubftances. Lime and magnefia precipitate it in the form of a yellowifh powder. Alkalis exhibit the fame appearance; but an excefs of alkali rediffolves the precipitate. The precipitate of gold obtained from aqua regia by the addition of a fixed alkali, appears to be a true calx, and is foluble in the vitriolic, nitrous, and marine acids; from which however it feparates by ftanding, or by evaporation of the acids. The nut gall precipitates gold of a reddifh colour, very foluble in the nitrous acid, to which it communicates a fine blue colour.

— volatile alkali.

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

poffeffes

GOLD.

Production of fulminating gold.

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

— Analysis.

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

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

Theory.

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

Precipitation of gold by liver of ſulphur:

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

— by metallic ſubſtances.

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

Proceſs for making the purple powder of Caſſius.

GOLD.

Procefs for making the purple powder of Caffius.

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

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

Obfervations.

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

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

Solutions of gold in ether, &c.

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

Gold refifts nitre:

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

— but is rendered pale by borax:

— unchanged by earths, alkalis, or fulphur.

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

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Procefs of dry parting.

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

Combination with liver of fulphur:

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

— with metals.

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

without combination. For as gold leaf tranfmits the green rays of light, it will eafily follow, that particles of filver, enveloped in particles of gold, will reflect a green inftead of a white light. GOLD.

A ftrong heat is neceffary to combine platina with gold; it greatly alters the colour of the gold if its weight exceed the forty-feventh part of the mafs: it does not much affect the ductility. The Spanifh miniftry has prohibited the exportation of platina from America, left it fhould be ufed in adulterating gold; but this does not appear to be a danger which need be feared, as chemiftry has long been in poffeffion of feveral fimple and expeditious methods of diftinguifhing this fraud, which befides is evident to the fight when the quantity of debafement is confiderable. It may be queftioned, likewife, whether the value of platina would not foon exceed that of gold, if its properties and ufes were better known in fociety. Combinations with metals. Platina. Vide p. 227, and alfo chap. iii. of this fection.

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

Lead unites with gold, and confiderably impairs its ductility. Copper renders gold lefs ductile, harder, more fufible, and of a deeper colour. This is the ufual addition in coin, and other articles ufed in fociety. Tin renders it brittle in proportion to its quantity; but it is a common error of chemical writers to fay that the flighteft addition is fufficient for this purpofe. With iron it forms a grey mixture, which obeys the magnet. This metal is very hard, and is — lead, copper, &c. Alchorne in Phil. Tranf. vol. 75.

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Combinations with metals.

ſaid to be much ſuperior to ſteel for the fabrication of cutting inſtruments. Biſmuth renders gold white and brittle; as do likewiſe nickel, arſenic, and antimony. Zinc produces the ſame effect; and, when equal in weight to the gold, a metal of a fine grain is produced, which is ſaid to be well adapted to form the mirrors of reflecting teleſcopes, on account of the fine poliſh it is ſuſceptible of, and its not being ſubject to tarniſh. The alloys of gold with the regulus of manganeſe or molybdena are not known. It could not be mixed with the regulus of wolfram, on account of the infuſibility of this laſt ſubſtance.

Native ores, or alloys of gold.

Gold is found moſtly in the metallic ſtate, though generally alloyed with ſilver, copper, iron, or all three. It is found either in ſeparate lumps, or viſible grains, among the ſands of rivers in many parts of Europe, and elſewhere. The quantity is for the moſt part inſufficient to pay the coſt of ſeparating it; but it is thought to be more univerſally diffuſed in ſands and earths than any other metal, except iron. The greateſt quantity of gold is imported into Europe from South America. Some is brought from the Eaſt Indian iſlands and China, and ſome from the coaſt of Africa. The principal gold mines in Europe are

Purification.

thoſe of Hungary. Some ſands afford gold by ſimple waſhing; the heavy metallic particles ſubſiding ſooneſt; but when it is bedded in earths or ſtones, theſe ſubſtances are pounded, and boiled with one tenth of their weight of mercury, together with water. The mercury, after a certain time, abſorbs the gold, and may be ſeparated by preſſure through leathern bags, and ſubſequent diſtillation. Or otherwiſe, if the

ſand

GOLD.

Auriferous fands

fand be heated red hot, and quenched in water feveral times, for the purpofe of cracking and dividing it, and the whole be then melted into glafs, with twice its weight of the calx of lead, called litharge, and charcoal powder be then added, the lead will be revived into the metallic ftate, and will carry the gold along with it. By expofure to a proper degree of heat, with accefs of air, the lead may again be converted into litharge, and the gold will be left pure. This laft operation is in fact a method of affaying fands which contain gold, rather than of obtaining it from them in the large way.

Pyrites containing gold.

Gold is alfo found in certain martial pyrites in Sweden and elfewhere; from which it may be extracted by torrefaction, or burning of the fulphur, and fubfequent digeftion in aqua regia.

Cupellation of gold.

To obtain gold in a ftate of purity, or to afcertain the quantity of alloy it may contain, it is expofed to a ftrong heat, together with lead, in a porous crucible. This operation is called cupellation, and is performed as follows: The precious metal is put, together with a due proportion of lead, into a fhallow crucible made of burned bones, called a cupel; and the fufion of the metals is effected by expofing them to a confiderable heat in a muffel, or fmall earthen oven, fixed in the midft of a furnace. The lead continually vitrifies, or becomes converted into a glaffy calx, which diffolves all the imperfect metals. This fluid glafs, with its contents, foaks into the cupel, and leaves the precious metal in a ftate of purity. During the cupellation, the fcoriæ running down on all fides of the metallic mafs, produce an

 appear-

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

Separation of gold from the perfect metals:

After gold has paffed the cupel, it may ftill contain either of the other perfect metals, platina or filver. The former is feldom fufpected; the latter is feparated by the operations called quartation and parting.

—by quartation:

Quartation confifts in adding three parts of filver to the fuppofed gold, and fufing them together; by which means the gold becomes one fourth of the mafs only. The intention of this is to feparate the particles of gold from each other, fo that they may not cover and defend the filver from the action of the pure nitrous acid, which is to be ufed in the procefs of

— and parting.

parting. Parting confifts in expofing the mafs, previoufly hammered, or rolled out thin, to the action of boiling aqua fortis of a due ftrength. If the acid be not too concentrated, it diffolves the filver, and leaves the gold in a porous mafs of the original form; but, if too ftrong, the gold is in a powdery form, which may be wafhed and dried. The weight of the original metal before cupellation, and after all the fubfequent ftages, ferves to afcertain the degree of finenefs of the ingot, or ore, of which it was a part.

Finenefs of gold.

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

four

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

The aſſay of ſmall work, by the touch.

In ſuch ſmall works as cannot be aſſayed by ſcraping off a part and cupelling it, the aſſayers endeavour to aſcertain its quality, or fineneſs, by the touch. This is a method of comparing the colour and other properties of a minute portion of the metal with thoſe of certain ſmall bars whoſe compoſition is known.

Touch-needles.

Theſe bars are called touch-needles; and they are rubbed upon the black baſaltes, which for that reaſon is called the touchſtone. Black flint, or pottery, will ſerve the ſame purpoſe. Sets of golden needles may conſiſt of—pure gold; pure gold $23\frac{1}{2}$ carats, with half a carat ſilver; 23 carats gold, with one carat ſilver; $22\frac{1}{2}$ carats gold, with $1\frac{1}{2}$ carat ſilver; and ſo forth, till the ſilver amounts to four carats; after which the additions may proceed by whole carats. Other needles may be made in the ſame manner, with copper inſtead of ſilver; and other ſets may have the addition conſiſting either of equal parts ſilver and copper, or ſuch proportions as the occaſions of buſineſs require.

Obſervations on the aſſay by the touch.

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

GOLD.

Assay by the touch.

not only compares the colour of the ftroke made upon the touchftone by the metal under examination with that produced by his needle, but will likewife attend to the fenfation of roughnefs, drynefs, fmoothnefs, or greafinefs, which the texture of the rubbed metal excites when abraded by the ftone. When two ftrokes perfectly alike in colour are made upon the ftone, he may then wet them with aqua fortis, which will affect them very differently if they be not fimilar compofitions: or the ftone itfelf may be made red-hot by the fire, or by the blow-pipe, if thin black pottery be ufed; in which cafe the phenomena of calcination will differ according to the nature and quantity of the alloy.

Affay of gold ores in the moift way.

Gold ores may be affayed in the moift way by pounding them very fine, weighing a determinate portion, and attempting their folution in nitrous acid, which will diffolve the matrix if it confift of calcareous earth; or, if it be felenite, the powder may be digefted in aqua regia as long as any metallic fubftance is taken up; after which the gold may be precipitated by an addition of vitriol of iron, which will caufe it to fall down in the metallic ftate.

Ufes of gold.

The principal ufe of gold is as the medium of exchange in coin; for which it has been chofen to occupy the firft place, on account of its fcarcity, its great weight, and its not being fubject to tarnifh. The gold coins of Great Britain contain eleven parts of gold, and one of copper.

Gold is likewife ufed in gilding; for which purpofe, as we have already fhewn, it is mechanically divided into leaves of extreme thinnefs. Thefe are ftuck upon

wood,

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

Water-gilding.

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

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

CHAP.

CHAP. II.

CONCERNING SILVER.

SILVER. Characters of silver.

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

Silver

SILVER.

Solubility of ſilver in acids.

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

Combination with nitrous acid.

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

SILVER. lunar nitre, the acid flying off, and the ſilver remaining pure. It is obvious that, for the purpoſe of forming the lunar cauſtic, it is not neceſſary to ſuffer the ſalt to cryſtallize, but that it may be made by evaporating the ſolution of ſilver at once to dryneſs; and as ſoon as the ſalt is fuſed, and ceaſes to boil, it may be poured out. The nitrous acid driven off from lunar nitre is decompoſed, the products being vital air and phlogiſticated air.

Lunar cauſtic.

Page 167, 168.

Although the nitrous acid diſſolves ſilver with ſuch great facility, it appears to do this only in conſequence of its great power to calcine the metal; for the vitriolic and marine acids have a greater attraction for the calx. They accordingly take it from that acid, and form ſalts; which, as we have already obſerved, fall to the bottom on account of their difficult ſolubility. The vitriol of ſilver, which is formed by pouring vitriolic acid into the nitrous ſolution of ſilver, is ſparingly ſoluble in water; and on that account forms cryſtals, which are ſo ſmall that they compoſe a white powder. The marine acid precipitates from nitrous acid the ſaline compound called luna cornea, or horn ſilver, which has been ſo diſtinguiſhed becauſe, when melted and cooled, it forms a ſemi-tranſparent and partly flexible maſs reſembling horn. It is ſuppoſed that a preparation of this kind has given riſe to the accounts of malleable glaſs.

Vitriol of ſilver.

Luna cornea.

Malleable glaſs.

If any ſalt with baſe of alkali, containing the marine acid, be added to the nitrous ſolution of ſilver, the ſame effect takes place by double affinity; the alkaline baſe uniting with the nitrous acid, and the ſilver falling down in combination with the marine acid.

Since

SILVER.

Very pure silver obtained from luna cornea.

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

Test of marine acid in waters.

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

Purification of nitrous acid.

Precipitates.

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

SILVER.

Preparation of fulminating silver.

inftances of chemical detonation hitherto known *. Pure filver is diffolved in pale nitrous acid, and precipitated by the addition of lime-water. This calx, or precipitate, after decantation of the fluid, is to be dried by expofure to the air for three days. The inventor thinks the prefence of light has fome influence in the fuccefs of the experiment. The dried calx being agitated or ftirred in a folution of cauftic volatile alkali, affumes the form of a black powder, from which the fluid is to be decanted, and the black fubftance left to dry in the air. This is the fulminating filver.

Its effects.

Gunpowder and fulminating gold are not to be compared with this new product; as the former requires ignition, and the latter a fenfible degree of heat, to caufe them to fulminate. But the flighteft agitation or friction is fufficient to caufe the fulminating filver to explode. When it is once obtained, it can no more be touched. The falling of a few atoms of this preparation from a fmall height produced the detonation; a drop of water falling upon it had the fame effect. No attempts therefore can be made to inclofe it in a bottle; but it muft remain in the capfule wherein, by evaporation, it obtained this terrible property.

Precautions.

To make this experiment with fafety, it is proper to ufe no greater quantity than a grain of filver; the laft deficcation fhould be made in a metallic veffel; and the face of the operator fhould be defended by

* Difcovered by Berthollet. See the Journal de Phyfique for June 1788, p. 474.

a mafk

SILVER.

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

Fulminating filver.

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

Theory of the inventor, page 225:

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

— by the phlogiftic hypothefis.

Keir's compound acid, page 169.

It is a valuable difcovery of Mr. Keir *, that a mixture of ftrong vitriolic acid with the nitrous acid, or nitre, is a powerful folvent of filver, though it fcarcely

* Phil. Tranf. 1780. p. 367.

acts upon the other metals. This is of confiderable importance in the Birmingham manufactures, where the filver in the cuttings of plated copper is required to be feparated from this laft metal. For this purpofe the pieces of metal are put into a glazed earthen pan, and a compofition of eight or ten pounds of oil of vitriol, with one pound of nitre, is poured upon them, ftirred about, and the action of the fluid affifted by a heat between 100° and 200° of Fahrenheit. When the liquor is nearly faturated, the filver is to be precipitated by common falt, which may be eafily afterwards reduced; or, otherwife, the filver may be precipitated in its metallic ftate by adding to the folution a few of the pieces of copper, and a fufficient quantity of water, which enables the liquor to act on the copper. The theory of this effect ftill remains to be inveftigated.

Sulphur combines readily with filver in the dry way; but may be feparated by a ftronger heat. The fulphur of liver of fulphur likewife blackens filver, and combines with it, whether the filver be immerfed in the liquid folution, or expofed to hepatic air.

Action of aqua regia upon filver.

Aqua regia acts ftrongly on filver; but precipitates it in the form of luna cornea as faft as it is diffolved. This effect may be eafily underftood by confidering that the nitrous acid diffolves the filver, and the marine precipitates it.

The neutral falts alone do not alter filver either in the moift or dry way; nitre, in particular, does not deflagrate with this metal.

Precipitation of filver by metals.

Moft metallic fubftances precipitate filver in the metallic ftate from its folution. The affayers make ufe

ufe of copper to feparate the filver from the nitrous acid ufed in the procefs of parting. The precipitation of filver by mercury is very flow, and produces a peculiar fymmetrical arrangement, called the tree of Diana. In this, as in all precipitations, the peculiar form may be affected by a variety of concomitant circumftances; for which reafon one procefs ufually fucceeds better than another. Lemery directs that an ounce of fine filver be diffolved in a fufficient quantity of very pure and moderately ftrong nitrous acid; that this folution be mixed in a matrafs, or bottle, with about twenty ounces of diftilled water; and that, after the addition of two ounces of mercury, the whole be fuffered to repofe. During the fpace of forty days a kind of tree of filver will be formed on the furface of the mercury, with branches greatly refembling a vegetable fubftance in its ramifications. The foregoing procefs is faid by Macquer to fucceed very well; but the following, of Homberg, is much fhorter.

SILVER.

Tree of Diana.

Procefs of Lemery.

Make an amalgam, without heat, of four drams of leaf filver, with two drams of mercury. Diffolve this amalgam in four ounces, or a fufficient quantity of pure nitrous acid of a moderate ftrength; dilute this folution in about a pound and a half of diftilled water; agitate the mixture, and preferve it for ufe in a glafs bottle, with a ground ftopper. When this preparation is to be ufed, the quantity of one ounce is put into a phial, and the fize of a pea of an amalgam of gold or filver, as foft as butter, is to be added; after which the veffel muft be left at reft. Soon afterwards fmall filaments appear to iffue out of the

Homberg's procefs for making the tree of Diana.

SILVER.

ball of amalgam, which quickly increafe, and fhoot out branches in the form of fhrubs.

Theoretical obfervations.

In the above experiment of Lemery the nitrous acid depofits its filver at the fame time that it takes up mercury; and, in confequence of the liquor being fo much diluted, the procefs goes on flowly, and the precipitated filver has time to arrange itfelf according to the law of its cryftallization, whether that depend on the polarity of its particles, or on any other property not yet explained. In the method of Homberg there are two circumftances which appear calculated to forward the procefs: in the firft place, the nitrous acid already contains mercury in folution, which may probably render it more difpofed to part with the filver; and, in the next place, the mercury is combined with filver or gold in the form of an amalgam. Thefe may perhaps facilitate the precipitation of the filver, by prefenting a bafe for it to combine with; which may be more perfectly at repofe, becaufe lefs agitable than the fluid mercury in the former experiment. After all, however, though the general theory of the experiment is not difficult, yet it does not feem eafy to point out the effectual caufe of the differences between the two refults.

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Combinations of filver; with gold:

Silver unites with gold by fufion, and forms a pale alloy, as has been already mentioned in treating of that metal. With platina it forms a hard mixture, rather yellower than filver itfelf, and of difficult fufion. The two metals do not unite well. Silver melted with one tenth part of crude platina, from which the ferruginous particles had been feparated by a ftrong magnet, could not be rendered clear

— with platina:

SILVER.

clear of fcabrous parts, though it was repeatedly fufed, poured out, and laminated between rollers. It was then fufed, and fuffered to cool in the crucible, but with no better fuccefs. After it had been formed, by rolling and hammering, into a fpoon for blow-pipe experiments, it was expofed to a low red heat, and became rough, and bliftered over its whole furface. The quantities were one hundred grains of filver, and ten grains of platina. Nitre was added during the fufions.

Combinations of filver with mercury:

Silver very readily combines with mercury. A very fenfible degree of heat is produced when filver leaf and mercury are kneaded together in the palm of the hand. With lead it forms a foft mafs, lefs fonorous than pure filver. With copper it becomes harder and more fonorous, at the fame time that it remains fufficiently ductile: this mixture is ufed in the Britifh coinage. Fifteen parts of filver, alloyed with one of copper, form the compound called ftandard filver. The mixture of filver and iron has been little examined. With tin it forms a compound which, like that of gold with the fame metal, has been faid to be brittle, however fmall the proportion; though there is probably as little foundation for the affertion in the one cafe as in the other. With bifmuth, arfenic, zinc, and antimony, it forms brittle compounds. It does not unite with nickel. The compound of filver and wolfram, in the proportion of two of the former to one of the latter, was extended under the hammer during a few ftrokes; but afterwards fplit in pieces.

—with lead:

—with copper:

—with tin, &c.

SILVER.

Native ſilver and its ores.

Silver is found either native or mineralized. The native ſilver is found in Peru, and various parts of Europe; ſometimes in conſiderable maſſes, and often diffuſed through ſand, ochre, or lime-ſtone. It is ſeldom pure, but is generally alloyed with copper, and ſometimes with gold, iron, or regulus of antimony. The mineralized ſilver contains ſulphur and arſenic, or both, with other admixtures.

Purifying of native ſilver.

Native ſilver may be purified by pounding or waſhing, or amalgamation with mercury; and the ſilver itſelf is refined by cupellation with lead in the ſame manner as gold. In the large way, the litharge, or vitrified lead, is blown from the ſurface of the ſilver by bellows, inſtead of ſoaking into the crucible. Gold may be ſeparated from ſilver by parting with aqua regia, or treatment with ſulphur in the dry way, which combines with the ſilver, and leaves the gold diſengaged.

Vitreous ore of ſilver.

The vitreous ſilver ore is the richeſt ore of ſilver, and contains from ſeventy to eighty pounds of ſilver in the hundred weight; the reſt being ſulphur, with rarely any other metal, except a ſmall portion of iron. It is found either in ſolid large lumps, or inherent in quartz or ſpar. Its colour generally reſembles that of lead; but grows dark by expoſure to the air. It uſually poſſeſſes a ſlight degree of malleability, and is ſufficiently ſoft to be cut by a knife.

Analyſis in the moiſt way:

To analyſe this ore in the moiſt way, it may be boiled in nitrous acid, which acidifies the ſulphur, and cauſes great part to fly off in the form of vitriolic acid air. Common ſalt, or marine acid, will precipitate

SILVER.

pitate the ſilver in the form of luna cornea, which may be either reduced or accounted for by deducting one fourth of its weight when waſhed and dried, which fourth of its weight is marine acid.

— in the dry way.

In the dry way, it may be reduced by expoſing it to a heat not ſufficient to melt it. In this way the ſulphur is diſſipated, and the ſilver remains uſually in a fibrous form. Small portions may be conveniently decompoſed in this manner by the blow-pipe upon charcoal.

Red ſilver ore.

The red ſilver ore is a heavy ſhining ſubſtance, either tranſparent or opake; ſometimes grey or blackiſh, but always reddiſh when powdered: it uſually contains more than half, and ſometimes $\frac{3}{4}$ of its weight of ſilver, the reſt being arſenic and ſulphur.

Analyſis in the moiſt way.

In the moiſt way, this ore is analyſed by reducing it to fine powder, and boiling it with diluted nitrous acid. The reſidue, which contains the ſulphur and the arſenic, muſt be edulcorated with water; and the arſenic may be diſſolved by boiling in a ſufficient quantity of aqua regia If the ſulphur ſhould retain any luna cornea, it may be ſeparated by keeping it for ſome days in a cloſed veſſel, with its own weight of diluted cauſtic volatile alkali. The clear nitrous ſolution being mixed with the water uſed in the eduſcoration, affords a precipitate of luna cornea by the addition of ſea ſalt, which may either be reduced or accounted for in the ſame manner as in the aſſay of the vitreous ſilver ore.

White ore of ſilver analyſed.

Silver united with ſulphur, arſenic, and copper, is generally called the white ore of ſilver. One hundred grains of this being reduced to a powder, and gently

 boiled

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boiled for an hour in more than twelve times its weight of diluted nitrous acid, the copper and silver are dissolved, and a white residuum remains. The silver is precipitated in the metallic form by the immersion of a clean plate of copper; and the copper being afterwards precipitated by the addition of volatile alkali, may be accounted for by allowing 194 grains of the precipitate to one hundred of the copper, and deducting the loss sustained by the plate of copper which was immersed in the solution. The white residuum may be deprived of its arsenic and iron by boiling in marine acid. The arsenic may be precipitated by the addition of water; and afterwards the iron, if any, by Prussian alkali. The undissolved sulphur may be treated with volatile alkali, to try whether it contains either copper or luna cornea.

The other ores of silver, of which there is considerable variety, may be analysed by varying the processes according to the supposed or known general contents of the ore *.

Method of assaying silver, or its ores, in the dry way.

Sulphureous and arsenical silver ores may be assayed by roasting and subsequent fusion with a greater or less quantity of flux. In the fusion, the silver is obtained alloyed with lead, copper, or iron, which may be separated by cupellation with lead, and the silver left pure. The fineness of silver is denoted by the assayers, by mentioning the number of pennyweights and grains of pure silver contained in the ounce. So

See page 231.

* For which consult Bergman's Treatise on the Art of Assaying in the Humid Way, inserted in the 2d vol. of the English translation of his Opuscula, or Essays.

that

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that if an ounce of ſilver be found to loſe half a pennyweight by cupellation, it is ſaid to be eleven pennyweights twelve grains fine; if it loſe a whole pennyweight, it is ſaid to be eleven pennyweights fine, &c. Silver is likewiſe tried by the touch, in the ſame manner as gold. For this purpoſe, the aſſayers are provided with a ſet of needles or ſmall bars; the firſt of which contains $\frac{1}{16}$ part of its weight of copper, and the reſt ſilver; the ſecond contains $\frac{2}{16}$ parts of copper; the third $\frac{3}{16}$ parts; and ſo on to the laſt, which contains 15 parts of copper to one of ſilver. By the reſemblance of colour on the touchſtone, an eſtimate may be made of the fineneſs of the ſilver to ſomething nearer than the 30th part of the whole, which is a conſiderable acquiſition in the examination of ſmall articles, ſuch as rings, trinkets, and the like. It is true indeed that the uſe of the touch ſuppoſes the precious metal to be alloyed with copper only, which may not be the caſe; and conſequently the aſſayer is liable to be deceived in this reſpect: but he may in this caſe have recourſe to aqua fortis, or the blow-pipe, in the ſame manner as directed in the foregoing chapter.

Page 23[illegible], 234.
Aſſay of ſilver by the touch.

In the large works, where ſilver is extracted, the proceſſes are grounded on the properties already deſcribed. Native ſilver is triturated with mercury; after which the amalgam is waſhed, to ſeparate the earthy particles; and the quickſilver ſeparated, partly by preſſure in leathern bags, and partly by diſtillation in iron retorts.

Extraction of ſilver from ores in the large way, by amalgamation:

Rich ſulphureous ores are roaſted, and fuſed with lead, to refine the ſilver by cupellation. The poorer ores,

— by fire.

SILVER.

ores, which contain copper, are fused with pyrites, which affords a mass consisting of copper, sulphur, and silver. Lead is then added, and the mass treated in the way of eliquation. The lead flows out, carrying the silver with it; and, lastly, these two metals are separated by the test, on which the lead is converted into litharge, and the silver remains pure.

Uses of silver.

The uses of silver are well known: it is chiefly applied to the forming of various utensils for domestic use, and as the medium of exchange in money. Its disposition to assume a black colour by tarnishing, and its softness, appear to be the chief objection to its use in the construction of graduated instruments for astronomical and other purposes, in which a good white metal would be a desirable acquisition.

CHAP.

CHAP. III.

CONCERNING PLATINA.

PLATINA.

Characters of platina.

PLATINA is one of the metals for the diſcovery of which we are indebted to our cotemporaries. It has yet been found only in Spaniſh America, among the gold mines there. We receive it in the form of ſmall particles, from the minuteſt size up to that of a pea; though theſe laſt are very seldom met with. Its particles or grains are ſmooth, irregularly figured with round edges, and are flattened, probably by hammering in the mills in which the gold is amalgamated.

Crude platina.

Theſe grains are of a whiter colour than iron, and are conſiderably malleable. In the ſtate in which we receive them, they are often mixed with ferruginous ſand, which may be ſeparated by the magnet; and alſo with grains of quartz or cryſtal. When it is ſeparated from heterogeneous particles, the crude platina itſelf is ſlightly magnetic, and is between ſixteen and eighteen times as heavy as water. The moſt violent fires are inſufficient to melt it, though its parts may be made to cohere together into a ſolid button by the ſtrong heat of a wind furnace. Burning lenſes of the moſt powerful kind fuſe it, and convert it into a malleable metal; and ſmall portions of crude platina may be eaſily melted upon charcoal, by flame urged by a ſtream of vital air.

Pure platina.

Pure or refined platina is by much the heavieſt body in nature. It is very malleable, though conſiderably

PLATINA.

Characters of platina.

derably harder than either gold or ſilver; and it hardens much under the hammer. Its colour on the touch-ſtone is not diſtinguiſhable from that of ſilver. When in the higheſt degree of purity, it is not magnetical; but when its ſpecific gravity is as low as 21.36 it contains iron ſufficient to render it magnetical. Pure platina requires a very ſtrong heat to melt it; but when urged by a white heat, it is ſaid that its parts will adhere together by hammering. This property, which in iron is diſtinguiſhed by the name of welding, is peculiar only to platina and that metal, which reſemble each other likewiſe in their infuſibility.

Welding.

Solution in dephlogiſticated marine acid:

Platina is not altered by expoſure to air; neither is it acted upon by the moſt concentrated ſimple acids, even when boiling, or diſtilled from it. The dephlogiſticated or aërated marine acid diſſolves it, as does likewiſe aqua regia; and both are ſaid to form the ſame ſalts with it. In this particular of ſolubility platina reſembles gold.

— in aqua regia.

The aqua regia beſt adapted to the ſolution of platina is compoſed of equal parts of the nitrous and marine acids. The ſolution does not take place with rapidity. A ſmall quantity of nitrous air is diſengaged; the colour of the fluid becoming firſt yellow, and afterwards of a deep reddiſh brown, which, upon dilution with water, is found to be an intenſe yellow. This ſolution is very corroſive, and tinges animal matters of a blackiſh brown colour: it affords cryſtals by evaporation. The metal is precipitable from its ſolution by ſal ammoniac; a property by which it is diſtinguiſhed from all other metals, in the ſame

Diſtinctive character.

manner

PLATINA.

nanner as the solution of gold is characterized by its precipitation upon the addition of martial vitriol. In this way, a compound solution of gold and platina may be separated by precipitating either of the two metals at pleasure. The orange-coloured precipitate of platina, obtained by means of sal ammoniac, is a saline substance, completely soluble in water; but its component parts have not been well ascertained. It is fusible without addition by a good forge furnace, and forms a brilliant, dense, and close-grained button, which is not malleable, probably on account of part of the saline substance not being dissipated. The same precipitate, exposed to the stronger heat of a blast furnace, was fused into a perfectly malleable regulus*.

Separation of gold from platina.

Malleable platina.

Alkalis and the soluble earths precipitate platina in the form of a calx from its solution. The Prussian alkali hereafter to be described does not precipitate it as it does all other metals; but it throws down a plentiful blue precipitate, consisting of iron, which was contained in the Prussian blue. This property therefore affords a method of separating the iron from platina, which always contains it. The vola-

Precipitates.

* By the Count de Milly. See Magellan's Cronstedt, page 574.—I have several small specimens of this platina, which is in thin plates or bars; their specific gravity is above $21\frac{1}{2}$; in which I do not pretend to a greater accuracy than $\frac{1}{200}$th part of the weight, because the quantities are so small. It is perfectly malleable, hard, and elastic, and obeys a strong magnet when the pieces are floated upon water: one small piece which was fused by Parker's lens is not at all magnetical, and seems to exceed 22 in specific gravity.

tile

PLATINA.

tile alkali precipitates platina of an orange yellow colour. Neutral ſalts, with baſe of fixed alkali, do not precipitate it.

Precipitates.

Moſt of the metals precipitate platina from its ſolution; but it does not in general fall down in the metallic ſtate.

This metal is not affected in the dry way by ſaline ſubſtances. Calx of arſenic facilitates its fuſion and the ſemi-metal forms a brittle compound with the platina. Mr. Achard ſucceeded in making crucibles of platina, by fuſing equal parts of platina, white arſenic, and vegetable alkali. This matter, when cooled, was reduced to a powder, and rammed into the mould of the veſſel intended to be formed. A ſtrong heat, quickly raiſed, and continued for ſome time, fuſed the maſs; and, after diſſipating the arſenic and the alkali, left the platina in the form deſired.

Crucibles of platina.

Combinations of metals.

Platina does not readily combine with gold, except by a ſtrong heat; and it greatly debaſes the colour of that metal: it does not readily unite with ſilver; to which however it communicates part of its hardneſs, while it impairs its colour and brilliancy. It altogether reſiſts the action of mercury; or at leaſt this mutual action does not ſeem to be ſtronger than that of mercury and iron. Lead and platina unite very well by fuſion; the lead becomes much leſs ductile, and even brittle, according to the proportions of the platina. In the attempts to cupel platina with lead, the proceſs went on as it does uſually with ſilver and gold in the beginning; but as ſoon as a conſiderable portion of the lead was diſſipated, the platina fixed, and the operation ceaſed. But with a ſtronger heat,

Cupellation.

PLATINA.

Combinations with metals.

heat, ſuch as that of a porcelain furnace, the operation may be completed, and malleable platina obtained free from lead. It has not been united with forged iron; but with caſt iron it formed a brittle compound. With copper it melts with conſiderable facility; and in due proportions forms a compound which takes a very beautiful poliſh, and is not ſubject to tarniſh: this has been uſed for the mirrors of reflecting teleſcopes. Tin and platina melt very eaſily, and form a compound, ſcarcely ductile when the tin abounds, but very brittle when the platina predominates. Biſmuth and antimony unite with platina by fuſion, and form brittle compounds, which do not promiſe to be of any conſiderable utility. Zinc likewiſe combines readily with it, and renders it very fuſible; this alloy is brittle, hard, and of a blueiſh colour. Wolfram can ſcarcely be brought to ſhew any ſign of union with platina. Cobalt, manganeſe, and molybdena have not been tried.

CHAP.

CHAP. IV.

CONCERNING MERCURY.

MERCURY. Characters of mercury.

MERCURY is diftinguifhed from all other metals by its extreme fufibility, which is fuch that it does not take the folid ftate until cooled to the thirty-ninth degree below o on Fahrenheit's thermometer; and of courfe it is always fluid in the temperate climates of the earth. Its colour is white, and rather bluer than filver. In the folid ftate it is malleable *; its fpecific gravity is greater than that of any of the other metals, platina, gold, and wolfram excepted. It is volatile, and rifes in fmall portions at the common temperature of the atmofphere, as is evinced by feveral experiments, more efpecially in a vacuum, fuch as obtains in the upper part of a barometer tube. At the temperature of about fix hundred degrees it boils rapidly, and rifes copioufly in fumes. Few of the other metals melt at fo low a temperature as the boiling point of mercury. When expofed to fuch a heat as may caufe it to rife quickly in the vaporous form, it gradually becomes converted into a red calx, provided vital air be prefent. This is known by the name of precipitate per fe. A greater heat however revives this metallic calx, at the fame time that the vital air is again extricated.

Precipitate per fe.

* The reader will find an ample account of the freezing of quickfilver in Dr. Blagden's Hiftory, Vol. LXXIII. of the Philofophical Tranfactions.

MERCURY. Characters.

Mercury is not perceptibly altered by expofure to the air; though by long agitation, with accefs of air, it becomes converted into a black powder or calx, which gives out vital air by heat, the metal being at the fame time revived. This metal is difpofed to attract moifture; and cannot, for that reafon, be ufed in the conftruction of barometers and thermometers until it has been firft boiled in an open veffel for the fpace of about half an hour.

Electric light.

When mercury is agitated in a dry glafs bottle, the friction between the metal and the glafs produces electricity. If the bottle be imperfectly exhaufted, this electricity paffes into the vacuum, and produces a light which was formerly thought to be a proof of the perfection of the vacuum in the upper part of barometer tubes; but which in fact does not appear in fuch barometers as have been cleared of air by careful boiling in the tube.

Action of vitriolic acid on mercury.

The vitriolic acid does not act on this metal, unlefs it be well concentrated and boiling. For this purpofe, mercury is poured into a glafs retort, with near twice its weight of vitriolic acid. As foon as the mixture is heated, a ftrong effervefcence takes place, vitriolic acid air efcapes, the furface of the mercury becomes white, and a white powder is produced; when the vitriolic air ceafes to come over, the mercury is found to be converted into a white, opake, cauftic, faline mafs, at the bottom of the retort, which weighs one third more than the mercury, and is decompofed by heat. Its fixity is confiderably greater than that of mercury itfelf. If the heat be raifed, it gives out a

MERCURY.

considerable quantity of vital air, the mercury being at the same time revived.

Vitriol and calx of mercury.

The white mass produced by the action of vitriolic acid upon mercury, consists partly of a saline mass, or vitriol of mercury, and partly of a calx, or mercury united to vital air (simply, according to the new theory; or deprived of phlogiston, according to the old theory, which phlogiston is supposed to enter into the combination of the vitriolic acid air). Water separates the salt from the calx, which last is then of a yellow colour. Much washing is required to produce this colour, if cold water be used; but if a large quantity of hot water be poured on, the calx immediately assumes a bright lemon colour. In this state, it is called turbith mineral.

Turbith mineral.

The vitriol of mercury affords a salt by evaporation, in small needle-formed deliquescent crystals. The addition of a large quantity of water, more especially if heated, decomposes vitriol of mercury, which deposits turbith mineral, unless there be an excess of acid in the fluid.

Precipitates.

The fixed alkalis, magnesia, and lime, precipitate mercury from its solution: these precipitates are reducible in closed vessels by mere heat without addition.

Solution in nitrous acid.

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The nitrous acid rapidly attacks and dissolves mercury, at the same time that a large quantity of nitrous air is disengaged; and the colour of the acid becomes green during its escape. Strong nitrous acid takes up its own weight of mercury in the cold; and this solution will bear to be diluted with water. But if the solution be made with the assistance of heat, a much larger quantity is dissolved; and a precipitate of calx will

will be afforded by the addition of diftilled water, which is of a yellow colour if the water be hot, or white if it be cold, and greatly refembles the turbith mineral produced with vitriolic acid: it has accordingly been called nitrous turbith. If acid be added to the folution made with heat, it lofes its property of being decompofed by water. This decompofition is not complete, but only deprives the acid of the redundant calx. MERCURY. Nitrous turbith.

All the combinations of mercury and nitrous acid are very cauftic, and form a deep purple or black fpot upon the fkin. They afford cryftals, which differ according to the ftate of the folution. When nitrous acid has taken up as much mercury as it can diffolve by heat, it ufually affumes the form of a white faline mafs. When the combination of nitrous acid and mercury is expofed to a gradual and long continued low heat, it gives out a portion of nitrous acid, and becomes converted into a red fubftance, fimilar in all refpects to the red calx of mercury formed by fimply heating it in contact with vital air. This is known by the name of red precipitate. Mercurial nitre. Red precipitate:

When red precipitate is ftrongly heated, a large quantity of vital air is difengaged, together with fome phlogifticated air, and the mercury is fublimed in the metallic form. —decompofed.

Mercurial nitre is more foluble in hot than cold water, and affords cryftals by cooling. It is decompofed by the affufion of a large quantity of water, unlefs the acid be in excefs.

When mercury is diffolved in nitrous acid by means of heat, nitrous air is emitted at firft; and after-

MERCURY.

Nitrous solution.

wards it ceases, though the solution still proceeds. The mercury which is taken up during the first part of the process is calcined, and the other portion is dissolved in the metallic state. If the solution be stopped in the first part of the process, fixed and volatile pure alkalis precipitate the yellow calx; but if the solution be continued after the escape of the elastic fluid has ceased, the precipitate obtained by the same means is black, on account of the admixture of metallic mercury, which may be separated from the yellow calx by distillation.

Precipitates.

Ponderous earth, magnesia, and lime, precipitate the nitrous solutions of mercury; and these precipitates, as well as all the other calces of this metal, are reducible by heat alone without addition.

Explosion of mercurial precipitates.

The precipitates of mercury from acids, by means of alkalis, possess the property of exploding when exposed to a gradual heat in an iron spoon, after having been previously triturated with $\frac{1}{6}$ of their weight of flowers of sulphur. The residue consists of a violet-coloured powder, which is converted by sublimation into cinnabar. It seems therefore as if the sulphur combined suddenly with the mercury, and expelled vital air in the elastic state.

Decomposition of the nitrous solution by other acids.

The vitriolic acid, or the salts containing it, decompose the nitrous solutions of mercury by virtue of the stronger attraction of the vitriolic acid to the metal. The precipitate which falls down does not essentially differ from the substance produced by the direct solution of mercury in the vitriolic acid. The marine acid likewise seizes the mercury dissolved in the nitrous acid, and forms a compound

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which

which falls to the bottom. This consists of a very caustic salt, which is called corrosive sublimate, and is produced when the nitrous solution contains only calx of mercury; but when that solution is saturated with metallic mercury, the compound which falls down by the addition of marine acid is called white precipitate, and does not differ from the preparation which, when made in the dry way, is called calomel, or mercurius dulcis.

Corrosive sublimate.

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Calomel.

The acetous and most other acids combine with the calx of mercury, and precipitate it from its solution in the nitrous acid.

The marine acid does not act perceptibly upon mercury in the metallic state; but the dephlogisticated or aërated marine acid readily dissolves it, and forms the same combination as arises from the direct union of marine acid with calx of mercury; that is to say, corrosive sublimate.

Combination of mercury with dephlogisticated marine acid.

The great specific gravity of mercury rendered it an object of peculiar attention to the alchemists and earlier chemists; many of whom hoped to fix it in the form of a solid substance, or to extract gold from it. From these motives, a great variety of processes have been made with it, by methods which are much less direct and simple than those of modern chemistry. Among others, the combination of the calx of mercury with marine acid is produced by several methods in the dry way by sublimation. In the large way, corrosive sublimate is prepared by triturating equal parts of mercury, common salt, and vitriol together, and exposing the whole to a moderate heat. The corrosive sublimate rises, and adheres to the upper part of the glass

Preparation of corrosive sublimate.

MERCURY.

Corrofive fublimate.

veffel. In this operation, the vitriolic acid from the vitriol is fuppofed to calcine the mercury, or to dephlogifticate the marine acid of the common falt; in either of which cafes the compound of marine acid with calx of mercury will be formed. From this theory, it will eafily be underftood that corrofive fublimate may be prepared by various methods. If the white mafs or calx of mercury, produced by expofing that metal to the action of vitriolic acid, be heated in a matrafs with an equal quantity of common falt, this fublimate will be had by double affinity; the vitriolic acid partly faturating the alkali, and the marine acid uniting with the calx of mercury, and rifing by fublimation. In the fame manner, the nitrous mercurial falt, or the mercurial precipitates, may be ufed inftead of the calx of mercury by vitriolic acid.

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Caufticity of metallic falts.

As the caufticity of metallic falts depends chiefly on the difpofition of the calcined metal to refume the metallic ftate, at the fame time that it burns or calcines the fubftance to which it may be applied; it is accordingly found that corrofive fublimate poffeffes this property in the moft eminent degree; it is therefore one of the moft active mineral poifons. This falt is foluble in water, though fparingly, and alfo in ardent fpirit. It is precipitated of an orange colour by fixed alkalis. The abforbent earths likewife throw down its calx. Volatile alkali affords a white precipitate, which foon afterwards affumes a flate colour.

Sal alembroth.

Corrofive fublimate becomes much more foluble in water by the addition of fal ammoniac, with which it forms a triple compound, called fal alembroth by the alchemifts, which cryftallizes by cooling. The

6 addi-

addition of a fixed alkali throws down a white calx of mercury, called white precipitate in the difpenfatories.

MERCURY. White precipitate.

The preparation of calomel is ufually made by triturating corrofive fublimate in a glafs mortar with fluid mercury, added by a little at a time, until no more can be made to difappear. A fmall quantity of water added to the corrofive fublimate during this part of the procefs, prevents that falt from rifing in the form of noxious duft. In this ftate, the combination is the fame as that obtained from the faturated nitrous folution of mercury by the addition of marine acid. The mixture of corrofive fublimate and mercury is more perfectly combined by expofing it to fublimation. It adheres to the internal part of the fubliming veffel in the form of a white mafs, of a ftriated texture. If there be any fufpicion of its containing corrofive fublimate, which is not probable on account of the more volatile nature of the latter, they may be feparated by means of warm water, the calomel being infoluble.

Preparation of calomel, or mercurius dulcis.

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When one part of antimony, which is the native combination or ore of antimony with fulphur, is triturated or accurately mixed with two parts of corrofive fublimate, and expofed to diftillation, the dephlogifticated or aërated marine acid combines with the regulus of antimony, and rifes in the form of the compound called butter of antimony; while the fulphur combines with the mercury, and forms cinnabar. If the regulus of antimony be ufed inftead of the mineral, the refidue which rifes laft confifts of running mercury, inftead of cinnabar.

Butter of antimony.

MERCURY.

Mercurial ethiops.

Mercury combines very readily with ſulphur. By trituration in a mortar the mercury diſappears, and forms a black compound with the ſulphur, which is called ethiops mineral, or mercurial ethiops. The combination is more ſpeedily made by mixing fluid mercury with melted ſulphur. In this way three parts of flowers of ſulphur unite with one of mercury. If the ſulphur be ſet on fire, the greateſt part burns, and the remainder is of a violet colour when pulverized. This conſiſts of a more intimate combination of mercury and ſulphur. It riſes in a heat nearly approaching to redneſs; and the ſublimate, which is called cinnabar, contains about $\frac{1}{5}$ part ſulphur, and the reſt mercury. The pigment called vermilion conſiſts of artificial cinnabar reduced to a powder.

Cinnabar or vermilion formed in the dry way:

Livers of ſulphur are decompoſed in the humid way by mercury, which unites with the ſulphur. With the fixed alkaline livers of ſulphur it forms a black powder, or ethiops, by agitation, which in the courſe of a number of years becomes red; but the volatile alkaline hepar, or fuming liquor of Boyle, converts mercury into a fine cinnabar in a very ſhort time. Turbith mineral, and the precipitates of mercury, are likewiſe converted into cinnabar by this alkaline hepar.

— in the humid way.

Unguents, &c.

Mercury unites by trituration with oils and mucilages, with which it forms black or deep blue compounds. A ſmall part of the mercury in theſe ſeems to be in combination, and the reſt in a ſtate of extreme diviſion.

This metal can ſcarcely be exhibited in the dry way, on account of its volatility. The degree of heat required

MERCURY.

quired to convert it into the red calx called precipitate per fe, is rather lower than its boiling point, and a greater reduces it again to the metallic ftate. The calcination and reduction of mercury, without addition, afford one of the ftrongeft arguments in favour of the fyftem which rejects phlogifton.

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Red calx of mercury, or precipitate per fe.

In the production of the red calx of mercury, it is required that air be prefent, and the metal kept in a ftate of brifk evaporation. On this account it is found convenient that the veffel fhould be fo deep, and its aperture fo fmall, that the fumes may not make their efcape. It may be inferred that in this, as well as other calcinations, there is an abforption of vital air; more efpecially as vital air is expelled from the calx by heat *. When the experiment is made in clofed veffels by means of a body of the kind marked C, fig. 15, whofe neck is introduced beneath a jar containing common air over mercury, the vital part is abforbed, and phlogifticated or foul air remains; and afterwards, by an augmentation of heat, the mercury is revived, at the fame time that it reftores the conftitution of the air by the emiffion of the vital air. Ten days or a fortnight's conftant heat is required to convert a few grains of mercury into precipitate per fe in the fmall way.

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Amalgams.

Mercury being habitually fluid, very readily combines with moft of the metals, to which it communicates more or lefs of its fufibility. When thefe metallic mixtures contain a fufficient quantity of mer-

* Lavoifier, Traité Elémentaire de Chimie, page 35.

MERCURY.

cury to render them foft at a mean temperature, they are called amalgams.

Combinations of metals.

It very readily combines with gold, filver, lead, tin, bifmuth, and zinc; more difficultly with copper, arfenic, and regulus of antimony; and fcarcely at all with platina or iron: it does not unite with nickel or cobalt; and its action on manganefe, wolfram, and molybdena, is not known. Looking-glaffes are covered on the back furface with an amalgam of tin. In this operation, mercury is poured on tin foil, upon a flat ftone, and fpread with a feather till its union with the tin has brightened every part of its furface. A large quantity of mercury is then poured on, and the glafs is flided along the fluid furface; upon which it is afterwards preffed by weights, to exclude the fuperfluous mercury.

Native mercury and its ores.

Mercury is found native in flaty or quartzofe earths, or vifibly diffufed through maffes of clay or ftone. Native precipitate per fe, or calx of mercury, has alfo been found; and this metal has likewife been met with in combination with the vitriolic and marine acids. Its volatility may probably have caufed it to be overlooked in many minerals that may contain it. The greateft quantity of mercury is found in combination with fulphur, in the form of cinnabar. Mercury is a fcarce metal. Moft of the mercury in commerce is afforded by the mines of Idria in the Auftrian dominions, Almaden in Spain, and Guancavelica in Peru. The native mercury requires little more than wafhing to feparate it from its matrix. Cinnabar in the native ftate is frequently mixed with calcareous earth; in

n which caſe the mercury may be ſeparated by diſtilla- MERCURY.
on, becauſe the calcareous earth combines with and Decompoſition of
etains the ſulphur. Pure cinnabar may be decom- cinnabar.
ſed by the addition of about one third of its weight
f iron. In all caſes wherein pure mercury is re-
uired, it muſt be diſtilled from cinnabar, or its ſul-
hureous combination. For this purpoſe, the mercury
ıay be converted into ethiops, and diſtilled with twice
s weight of quicklime or iron filings. Mercury in Purity of mer-
ommerce is judged to be pure when it is perfectly cury.
uid, and runs in neat globules, without any pellicle
n its ſurface, or without ſoiling a funnel of clean
hite paper, through which it may be poured by a
ery ſmall aperture at bottom. If it leaves nothing
ehind after evaporation, its purity may be ſtill more
epended upon.

To analyſe native cinnabar, its ſtony matrix ſhould Humid analyſis
rſt be diſſolved in nitrous acid; and the cinnabar, of cinnabar.
eing diſengaged, ſhould be boiled in eight or ten
mes its weight of aqua regia, compoſed of three
arts nitrous, and one marine acid: the mercury may
ıen be precipitated in the metallic form by the addi-
on of zinc.

The uſes of mercury have already been mentioned Uſes of mercury.
ı the preſent chapter, and elſewhere. The amalga-
ıation of the noble metals, water-gilding, the making
f vermilion, the ſilvering of looking-glaſſes, and the
reparation of ſeveral powerful medicines, are the
rincipal uſes to which this metal is applied.

CHAP.

CHAP. V.

CONCERNING LEAD.

LEAD.

Characters of lead.

LEAD is a white metal, of a conſiderably blue tinge, very ſoft and flexible, not very tenacious, and conſequently incapable of being drawn into fine wire, though it is eaſily extended into thin plates under the hammer. Its weight is very conſiderable, being rather greater than that of ſilver. Long before ignition, namely at about the 540th degree of Fahrenheit's thermometer, it melts; and then begins to be calcined, if reſpirable air be preſent. In a ſtrong heat it boils, and emits fumes; during which time, if expoſed to the air, its calcination proceeds with conſiderable rapidity. If melted lead be poured into a box previouſly rubbed with chalk to prevent its action on the wood, and be continually agitated, it will concrete into ſeparate grains, of conſiderable uſe in various mechanical operations, particularly that of weighing. Lead is brittle at the time of congelation. In this ſtate it may be broken to pieces with a hammer, and the cryſtallization of its internal parts will exhibit an arrangement in parallel lines.

Granulated.

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Calcination.

This metal, during the progreſs of heat, firſt becomes converted into a duſky powder, which by a continuation of the heat becomes white, yellow, and afterwards of a bright red inclining to orange colour, called minium, or red lead. The proceſs requires conſiderable management with regard to the heat and acceſs

Minium, or red lead.

LEAD.

cefs of air, in the making of red lead. Many days are quired for this purpofe. If the heat be too great or oid, the lead becomes converted into a flaky fub- nce, called litharge; and a ftill greater heat con- rts it into a clear, tranfparent, yellow glafs, which werfully diffolves and corrodes metallic calces or rths; and on this account it ufually finds its way ough the crucibles in a fhort time. It acts more ficultly on argillaceous than on filiceous earths; ience it is found that veffels made of clay mixed th broken pottery are preferable to thofe that are mpofed of clay and fand. The calx of lead is a incipal ingredient in moft of the modern fine white ffes. It is more particularly calculated to form the nfe glafs ufed to correct the aberration arifing from lour in thofe telefcopes which are known by the me of achromatic; becaufe it communicates the operty of feparating the coloured rays from each ier in greater angles than obtain in alkaline glaffes equal angles of mean refraction. The imperfection iich moft confiderably affects this kind of glafs is, it its denfity is feldom uniform throughout. The egularities fhew themfelves in the form of veins, iich greatly difturb the regular refraction.

Litharge and glafs of lead.

Achromatic telefcope.

Lead is not much altered by expofure to air or ter; though the brightnefs of its furface, when cut fcraped, very foon goes off. It is probable that a n ftratum of calx is formed on the furface, which fends the reft of the metal from corrofion.

Action of air and water on lead:

Moft of the acids attack lead. The vitriolic acid es not act upon it, unlefs it be concentrated and iling. Vitriolic acid air efcapes during this pro- cefs,

— of vitriolic acid.

LEAD.

cess, and the acid is decomposed. When the distillation is carried on to dryness, a saline white mass remains, a small portion of which is soluble in water, and is the vitriol of lead: it affords crystals. The residue of the white mass is a calx of lead.

Combination of nitrous acid and lead.

Nitrous acid acts strongly on lead, and converts it into a white calx if the acid be concentrated; but if it be more diluted, the calx is dissolved, and forms a nitre of lead which is crystallizable, and does not afford a precipitate by cooling. It detonates on ignited coals. Lime and alkalis decompose the nitrous solution of lead. The vitriolic acid added to this solution combines with the metallic calx, and falls down. The marine acid in the same manner carries down the lead, and forms a combination called plumbum corneum, which is more soluble in water than the horn silver.

Plumbum corneum:

— marine acid:

Marine acid acts directly on lead by heat, which it calcines, and dissolves part of its calx. The marine salt of lead is crystallizable.

—acetous acid.

The acetous acid dissolves lead and its calces; though probably the access of air may be necessary for the solution of the metal itself in this acid. White lead, or ceruse, is made by rolling leaden plates spirally up, so as to leave the space of about an inch between each coil, and placing them vertically in earthen pots, at the bottom of which is some good vinegar. The pots are to be covered, and exposed for a length of time to a gentle heat in a sand bath, or by bedding them in dung. The vapour of the vinegar, assisted by the tendency of the lead to combine with the pure part of the air which is present,

White lead, or ceruse.

LEAD.

sent, corrodes the lead, and converts the external portion into a white calx, which comes off in flakes when the lead is uncoiled. The plates are thus treated repeatedly until they are corroded through. Ceruse is the only white substance used in oil paintings. It may be dissolved without difficulty in the acetous acid, and affords a crystallizable salt, called sugar of lead from its sweet taste. This, like all the preparations of lead, is a most deadly poison.

Sugar of lead.

Liver of sulphur precipitates lead from its solutions, the sulphur falling down in combination with the lead. Pure alkaline solutions dissolve a small portion of lead, and corrode a considerable quantity: the solution is said to give a black colour to the hair.

Action of liver of sulphur on lead: —of alkalis:

Oils dissolve the calces of lead, and become thick and consistent; in which state they are used as the basis of plasters, cements for water works, paint, &c.

—oils.

In the dry way, lead alone is calcined and vitrefied. When fused with fixed alkaline salts, it is converted into a dark-coloured scoria, partly soluble in water. The neutral salts in general are not acted upon by lead. Nitre calcines this metal when heated with it, though scarcely any commotion or apparent flame is produced by its action. Sulphur readily dissolves it in the dry way, and produces a brittle compound, of a deep grey colour and brilliant appearance, which is much less fusible than lead itself; a property which is common to all the combinations of sulphur with the more fusible metals.

Habitudes in the dry way.

The

LEAD. Habitudes with phoſphoric acid.

The phoſphoric acid, expoſed to heat together with charcoal and lead, becomes converted into phoſphorus, which combines with the metal. This combination does not greatly differ from ordinary lead: it is malleable, and eaſily cut with a knife; but it loſes its brilliancy more ſpeedily than pure lead; and, when fuſed upon charcoal with the blow-pipe, the phoſphorus burns, and leaves the lead behind.

Decompoſition of ſal ammoniac:

Lead decompoſes ſal ammoniac by the aſſiſtance of heat: its calces unite with the marine acid of that ſalt in the cold, and diſengage its volatile alkali. When volatile alkali is obtained by diſtilling ſal ammoniac with the calces of lead, the reſidue conſiſts of plumbum corneum.

— of common ſalt.

Litharge fuſed with common ſalt decompoſes it; the lead unites with the marine acid, and forms a yellow compound, at preſent uſed in this country as a pigment, for which an excluſive privilege has been granted. The alkali either floats at top, or is volatilized by the heat if ſtrongly urged. The ſame decompoſition takes place in the humid way, if common ſalt be macerated with litharge; and the ſolution will contain cauſtic alkali.

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Combinations of lead with metals.

Lead unites with moſt of the metals. Gold and ſilver are diſſolved by it in a ſlight red heat. Both theſe metals are ſaid to be rendered brittle by a ſmall admixture of lead, though lead itſelf is rendered more ductile by a ſmall quantity of them. Platina forms a brittle compound with lead; mercury amalgamates with it; but the lead is ſeparated from the mercury by agitation, in the form of an impalpable

LEAD.

black powder, vital air being at the ſame time abſorbed. The preſence of vital air is indiſpenſably neceſſary in this proceſs. Copper and lead do not unite but with a ſtrong heat. If lead be heated ſo as to boil and ſmoke, it ſoon diſſolves pieces of copper thrown into it; the mixture when cold is brittle. The union of theſe two metals is remarkably ſlight; for upon expoſing the maſs to a heat no greater than that in which lead melts, the lead almoſt entirely runs off by itſelf. This proceſs, which is peculiar to lead with copper, is called eliquation. The coarſer ſorts of lead, which owe their brittleneſs and granulated texture to an admixture of copper, throw it up to the ſurface on being melted by a ſmall heat. Iron does not unite with lead, as long as both ſubſtances retain their metallic form. Tin unites very eaſily with this metal, and forms a compound which is much more fuſible than lead by itſelf, and is for that reaſon uſed as a ſolder for lead. Two parts of lead and one of tin form an alloy more fuſible than either metal alone: this is the ſolder of the plumbers. Biſmuth combines readily with lead, and affords a metal of a fine cloſe grain, but very brittle. A mixture of eight parts biſmuth, five lead, and three tin, will melt in a heat which is not ſufficient to cauſe water to boil. Regulus of antimony forms a brittle alloy with lead. Wolfram unites with it into a ſpongy ductile compound, which ſplits into leaves when hammered. Nickel, cobalt, manganeſe, and zinc, do not unite with lead by fuſion.

Combinations of lead and copper; decompoſed by eliquation, or by low heat.

Plumbers ſolder.

Fuſible mixture.

T All

LEAD.

Revival of the calces of lead.

All the calces of lead are very eafily revived. Minium, when expofed to a ftrong heat, gives out part of the vital air it abforbed during its calcination; but, like the other calces of this metal, it requires the addition of fome combuftible fubftance for its complete revival. A familiar inftance of this revival is feen by expofing the common wafers to the flame of a candle. Thefe wafers are coloured with minium, which is revived by the heat and inflammable fubftance of the wafer, fo that it falls down in metallic globules.

Native lead and its ores.

Lead is found native, though feldom; and alfo in the form of a calx, called native cerufe, or lead ochre, or lead fpar of various colours, red, brown, yellow, green, blueifh, and black.

Analyfis of calciform ores.

Thefe ores, when freed as much as poffible from earthy matter, may be diffolved in diluted nitrous acid. Calx of iron is ufually thrown down from the folution by boiling. If the lead be then precipitated by the mild mineral alkali, and weighed, 132 grains of the dry precipitate will correfpond with 100 grains of lead in the metallic ftate. If the precipitate be fufpected to contain copper, it may be feparated by digefting in volatile alkali. If it be fuppofed to contain filver and copper, the precipitate may again be diffolved in nitrous acid, and feparated by the addition of marine acid; which combining with the metal, produces luna cornea, and plumbum corneum; the latter of which, being foluble in 30 times its weight of boiling water, may be wafhed off, while the filver remains undiffolved; or the filver, if alone in the precipitate, may be taken

aken up by volatile alkali, which will leave the alx of lead of the ſame value with regard to eight as the foregoing. Lead is alſo found mine- Native ſalts of lead. alized by the vitriolic and the phoſphoric acids: ais laſt is of a greeniſh colour, ariſing from a aixture of iron. The vitriol of lead is ſoluble in bout 18 times its weight of water. One hundred nd forty-three grains of the dried ſalt repreſent 100 rains of lead. The phoſphoric lead ore may be Humid analyſis of phoſphoric lead ore. iſſolved in nitrous acid by means of heat, except a w particles of iron, which remain at the bottom. y the addition of vitriolic acid the lead is thrown own in the form of white flakes of vitriol; which, hen waſhed and dried, diſcover the quantity of lead ney contain, by the ſame allowance of 143 grains of ne ſalt to 100 grains of metallic lead. The remain- g ſolution being evaporated to dryneſs, affords phoſ- horic acid.

Lead is abundantly found in combination with Sulphureous ore of lead; or galena. lphur, in the form of heavy, ſhining, black, or ueiſh lead-coloured cubical maſſes, whoſe corners e uſually truncated; its texture is laminated, and s hardneſs variable. This is called galena, or potters ad ore. Moſt lead ores contain more or leſs of ver. When antimony enters into its compoſition, e texture is radiated or filamentous. There are ſo lead pyrites, which contain a conſiderable pro- ortion of iron and ſulphur; and red lead ſpar, hich conſiſts of lead mineralized by ſulphur and ſenic: this is very ſcarce.

If ſulphurated lead be boiled in nitrous or marine Analyſis of ſulphurated lead. id of a moderate ſtrength, the ſulphur may be

 obtained

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obtained pure, and collected on a filter. When iron or ftony particles are contained among the undiffolved part, the fulphur may be feparated by digeftion in a folution of cauftic fixed alkali, which converts it into liver of fulphur, and leaves the other infoluble matters behind. If the firft folution be made with nitrous acid, it may contain filver and lead, which, after precipitation by mild mineral alkali, may be feparated by the volatile alkali, as mentioned in the humid analyfis of the calciform ores: when the marine acid is ufed for the folution of the ore, a large quantity of plumbum corneum feparates, for want of a fufficient quantity of water to diffolve it. This requifite quantity of water muft be added to diffolve the falt before the precipitate is made by the fixed alkali.

Revival of lead by the blow-pipe.

All the ores of lead, except the phofphoric, are reducible to the metallic ftate by diffipating their volatile contents by the blow-pipe on a piece of charcoal. In the large way, they are revived by fufion with charcoal.

Ufes of lead.

The ores of this metal are abundantly found in the mine counties of England, and in various other parts of the globe. Its ufes are numerous, and fcarcely need be mentioned. Its calces have been already mentioned as of great ufe as a pigment, and in the manufacture of glafs. Lead is caft into thin fheets for covering buildings, making water-pipes, and various other ufes; and this is rolled between two cylinders of iron, to give it the requifite uniformity and thinnefs. Lead is thought, and with fome reafon, to be not perfectly innocent even for water-pipes,

pipes, and much lefs fo for any other kind of veffels. The workmen in any of the preparations of lead are generally fubject to a peculiar colic, and paralytic diforders; which moft probably arife from the internal ufe of the metal: for it is a fact that thefe workmen are not fufficiently cautious in wafhing their hands, or removing fuch particles of lead, or its preparations, as may cafually intermix with their food.

LEAD.

CHAP. VI.

CONCERNING COPPER.

COPPER. Characters of copper.

COPPER is a metal of a peculiar reddiſh brown colour; hard, ſonorous, very malleable, and ductile; of conſiderable tenacity, and of a moderate ſpecific gravity. At a degree of heat far below ignition the ſurface of a piece of poliſhed copper becomes covered with various ranges of priſmatic colours, the red of each order being neareſt the end which has been moſt heated; an effect which muſt doubtleſs be attributed to calcination, the ſtratum of calx being thickeſt where the heat is greateſt, and growing gradually thinner and thinner towards the colder part. A greater degree of heat calcines it more rapidly, ſo that it contracts thin powdery ſcales on its ſurface, which may be eaſily rubbed off; the flame of the fuel becoming at the ſame time of a beautiful blueiſh green colour. In a ſtrong white heat, nearly the ſame as is neceſſary to melt gold or ſilver, it melts, and exhibits a blueiſh green flame; by a violent heat it boils, and is volatilized partly in the metallic ſtate.

See Newton's Optics.

Corroſion of copper:

Copper ruſts in the air; but the corroded part is very thin, and preſerves the metal beneath from further corroſion.

— and ſolution in vitriolic acid.

The vitriolic acid, when concentrated and boiling, diſſolves copper. A brown thick fluid, containing calx of copper, and a portion of the calx combined with

COPPER.

with vitriolic acid, is found at the bottom of the folvent. If water be added to this, it forms a blue folution of copper, which by evaporation affords blue cryftals, that require about four times their weight of water to diffolve them. This folution lets fall a calx of copper of a green colour by long expofure to the air.

Vitriolic combinations and precipitates.

The folutions of copper in vitriolic acid are flightly cauftic. Magnefia, lime, and the fixed alkalis, precipitate the metal from them in the form of calx. Volatile alkali precipitates all the folutions of copper; but rediffolves the calx, and produces a deep blue colour. Copper is precipitable from moft of its folutions in the metallic ftate by the addition of iron: a clean plate of iron foon becomes covered with a coating of copper when immerfed in the folution: hence the volatile alkali, and the application of iron, are confidered as the tefts of the prefence of copper. There are certain mineral waters in Hungary, Sweden, Ireland, and in various parts of England, which contain vitriol of copper, and from which it is precipitated by the addition of pieces of old iron.

Nitrous combination of copper.

Nitrous acid diffolves copper with great rapidity, and difengages a large quantity of nitrous gas. Part of the metal falls down in the form of a calx; and the filtrated or decanted folution, which is of a much deeper blue colour than the vitriolic folution, affords cryftals by flow evaporation. This falt is deliquefcent, very foluble in water, but moft plentifully when the fluid is heated. Its folution, expofed to the air in fhallow veffels, depofits a calx of a green colour. Lime precipitates the metal of a pale blue; fixed

 alkalis,

COPPER.

alkalis, of a blueifh white. Volatile alkali throws down blueifh flocks, which are quickly rediffolved, and produce a lively blue colour in the fluid.

Solution of copper in marine acid:

Marine acid does not readily diffolve copper, unlefs it be concentrated and boiling. The folution is of a deep brown colour; but, on ftanding for fome time, it depofits a fediment, and becomes green. By careful evaporation it yields cryftals; or, when infpiffated, it affords a greenifh mafs, which deliquefces in the air, is readily diffolved in water, gives a green tincture to ardent fpirit, melts in a gentle heat, takes fire from a candle, and burns with a blue flame. The marine acid diffolves the calces of copper more readily than the metal itfelf; but the folution does not differ from the foregoing.

— in vegetable acids.

Vegetable acids diffolve copper flowly; but in con- derable quantity, if refpirable air be prefent. In this, as in a number of other metallic folutions, it appears that the difpofition of the air to calcine the metal is greatly affifted by the elective attraction of the acid for the metallic calx. Vinegar does not diffolve copper when boiling, becaufe the fteam prevents the accefs of the air; but the fame acid ftanding for a day in a copper veffel, will contract a dangerous metallic impregnation. This circumftance accounts for the unhappy confequences in fome inftances attending the ufe of copper veffels, which in other cafes have produced no noxious effects. Confectioners boil pickles, and even lemon juice, in clean copper veffels, without obferving any bad tafte or noxious confequence to follow. We cannot however avoid heartily concurring in the general opinion which now prevails,

Effect of the prefence of air.

vails, in the rejection of copper veffels for culinary purpofes. COPPER.

Verdigris is a calx of copper prepared in large quantities near Montpellier in France, by ftratifying copper plates with the hufks of grapes which remain after the juice has been preffed out. Thefe foon become acid, and corrode the copper. A folution of this calx in diftilled vinegar affords permanent cryftals, improperly called diftilled verdigris. Fabrication of verdigris.

Fixed alkalis have fome action on copper, with which they form a light blue folution. This, as well as the volatile alkaline folution, appears to fucceed better in the cold than by the affiftance of heat, for the fame reafon as the cold acetous acid acts upon copper; namely, the facility with which the metal is calcined by the accefs of air. Solution of copper in fixed alkalis:

Volatile alkali diffolves copper with much greater rapidity than fixed alkalis, whether it be in the metallic or calciform ftate; and forms a beautiful blue folution. This fluid has long attracted the notice of chemifts, on account of its becoming colourlefs in clofed veffels; and recovering its colour, which gradually extends from the furface downwards, when the veffel is opened. This effect is explained by the fuppofition, that the perfect folution of calx of copper in volatile alkali is colourlefs when the alkali is in excefs; but that it is blue when it abounds with calx of copper: and accordingly it is found that the lofs of colour on keeping the veffel clofed for fome time, and its re-appearance on opening the veffel, does not fucceed with old folutions, which are permanently blue. The air cal- — in volatile alkali.

cines

COPPER.

Habitudes of copper with volatile alkali:

cines more perfectly a portion of the suspended copper, which gives a blue colour to the fluid until it has more intimately combined with the alkali. If this combination be made in the closed vessel, the colour disappears; if it be made in the open vessel, the calcination of another portion goes on, and continues until the alkali is saturated, and can combine with no more: so that the last portion of perfect calx, which causes the blue colour, does not seem to have entered into so intimate a combination, for want of an excess of alkali. The alkali does not take up any considerable quantity when applied to copper filings; but it dissolves much more of the calces of copper. The solution does not very readily afford crystals.

— with oils, earths, alkalis, and neutral salts.

Oils do not seem to act upon copper until they become rancid; in which case their disengaged acid corrodes the copper, and the oil assumes a blueish green colour. Verdigris is soluble in ardent spirit. Copper in the metallic state does not unite with earths or alkalis in the dry way: its calces enter into the composition of glass. In general, it does not act on the neutral salts by fusion. Nitre detonates with it but difficultly. Filings of copper are thrown upon red-hot nitre; and the residue is a brownish grey calx, mixed, and partly combined, with vegetable alkali. If this be washed with water, the remaining calx may be fused, without other addition, into a deep opake brown glass, used by enamellers.

— sal ammoniac.

Sal ammoniac is decomposed by copper filings. The produce which comes over consists of caustic volatile

volatile alkali, rendered blue by a ſmall portion of copper, together with alkaline air, inflammable air, and phlogiſticated air: the reſidue conſiſts partly of marine ſalt of copper and calx. In this experiment we find that the copper detains the acid; while the volatile alkali, being ſet at liberty, comes over into the receiver. The inflammable and phlogiſticated air cannot ſo clearly be accounted for, as they may ariſe either from part of the alkali being decompoſed into its firſt principles; or the inflammable air may be ſupplied during the ſolution of the copper; in which caſe it will proceed from the phlogiſton of that metal, according to the hypotheſis of Stahl; or from a decompoſition of part of the water of cryſtallization of the ſal ammoniac; the pure air of which will be communicated to the copper, in order to calcine and render it ſoluble in the marine acid, while its inflammable air comes over in the elaſtic ſtate.

COPPER. Habitudes of copper with ſal ammoniac:

A ſolution of alum boiled in a copper veſſel depoſits ſome earth; and the fluid exhibits ſigns of the preſence of copper by the teſt of volatile alkali. This does not ſeem to be a perfect decompoſition of the alum; but appears to be effected by virtue of the acid, which that ſalt contains in exceſs. The neutral ſalt or alum, ſaturated with its own baſis, falls down, becauſe leſs ſoluble; while the exceſs of acid, forming vitriol of copper, exhibits the blue tinge when volatile alkali is added. — with alum.

Copper unites very readily with ſulphur. If copper filings be mixed with flowers of ſulphur and a little water, the combination takes place; but it is much more — with ſulphur.

COPPER.

more readily effected in the dry way. This cannot be done by direct fusion, because the sulphur is burned at a much less heat than is required to fuse the copper.

Combination of copper with sulphur:

It may be prepared by mixing equal parts of sulphur and copper filings together, and exposing them to heat, gradually raised to ignition: or plates of copper may be stratified in a crucible with sulphur, and gradually heated as before. This compound is a blackish grey mass; and is used by dyers and callico printers: it is distinguished by the name of æs veneris. Liver of sulphur dissolves copper both in the humid and dry way.

— with phosphorus.

Phosphorus unites with the calx of copper: or if the phosphoric glass be exposed to heat in a crucible, together with its weight of copper filings, and about $\frac{1}{8}$ of its weight of charcoal, the phosphorus which is formed combines with the copper into a kind of pyrites, which changes by exposure to air. It loses its metallic state, and assumes a black colour.

— with metallic substances.

The combinations of copper with the metals before treated of have been already mentioned. It unites imperfectly with iron in the way of fusion. Tin very readily combines with copper at a temperature much lower than is necessary to fuse copper alone. On this is grounded the method of tinning copper vessels. For this purpose, they are first scraped, or scoured; after which they are rubbed with sal ammoniac. They are then heated, and besprinkled with powdered resin, which defends the clean surface of the copper from acquiring the slight film of calx, which would prevent the adhesion of the tin to its surface. The melted tin is then poured in, and spread about.

An

COPPER.

An extremely ſmall quantity adheres to the copper; which may with great juſtice be ſuppoſed inſufficient to prevent the noxious effects of the copper as perfectly as might be wiſhed.

Bronzes and bell-metal.

When tin is melted with copper, it compoſes the compound called bronze. In this metal the ſpecific gravity is always greater than would be deduced by computation from the quantities and ſpecific gravities of its component parts. The uſes of this hard, ſonorous, and durable compoſition, in the fabrication of cannon, bells, ſtatues, and other articles, are well known. Bronzes and bell-metals are not uſually made of copper and tin only, but have other admixtures, conſiſting of lead, zinc, or arſenic, according to the motives of profit, or other inducements of the artiſt. But the attention of the philoſopher is more particularly directed to the mixture of copper and tin, on account of its being the ſubſtance of which the ſpeculums of reflecting teleſcopes are made. The metal required for this purpoſe ought to be capable of an exquiſite poliſh, hard enough to receive and retain a figure accurately ſuited to the regular reflection of light, and not ſubject to become tarniſhed by the action of the atmoſphere. Many excellent teleſcopes have been made with compoſitions of pure copper, alloyed with ſomewhat leſs than half its weight of tin. But it appears to be very well aſcertained, from the obſervations of the Aſtronomer Royal, that the ſpeculums of Mr. Edwards, whoſe compoſition was the reſult of numerous trials, are much ſuperior to any which have yet been made; and are even equal in light to acromatic

Metal for ſpeculums.

COPPER.

Edwards's method of making speculums.

matic telescopes of the same aperture, without altering the colours of objects. He first melts 32 parts of copper as fluid as possible, with one part of brass and one of silver, together with the black flux; at the same time that fifteen parts of tin are melted in a separate crucible by itself. These being taken from the fire, he pours the tin to the copper; immediately stirs the whole together with a wooden spatula, and pours it out hastily into a large quantity of cold water, which cools and granulates the composition. If the tin were fused together with the copper, or if they were to remain for any length of time in the extreme heat which is necessary to fuse this last metal, a part of the tin would be calcined, and the metal would abound more or less with small microscopic pores. If one of the pieces of the cold metal be broken, it will appear of a most beautiful bright colour, resembling quicksilver. Mr. Edwards affirms, that different kinds of copper require different doses of tin to produce the most perfect whiteness. If the dose of tin be too small, which is the fault most easily remedied, the composition will be yellowish; if it be too great, the composition will be of a grey blue colour, and dull appearance. He therefore finds by trial the quantity of tin necessary to be added in the second fusion to render the metal the most perfect. A much less degree of heat is then required to melt the compound. In the second melting he adds one part of arsenic, and immediately stirs the mixture; which he pours into the mould as soon as the fumes of the arsenic have ceased to rise. He casts the speculum

 culum

culum in ſand, with the face downwards; takes it out while red-hot, and places it in hot wood aſhes to cool; without which precaution it would break in cooling *.

COPPER. Metallic mixtures.

Copper unites with biſmuth, and forms a reddiſh white alloy. With arſenic it forms a white brittle compound, called tombac. With zinc it forms the compound called braſs, and diſtinguiſhed by various other names, according to the proportions of the two ingredients. It is not eaſy to unite theſe two metals in conſiderable proportions by fuſion, becauſe the zinc is burned or volatilized at a heat inferior to that which is required to melt copper; but they unite very well in the way of cementation. In the braſs works, copper is granulated by pouring it through a plate of iron, perforated with ſmall holes and luted with clay, into a quantity of water about four feet deep, and continually renewed: to prevent the dangerous exploſions of this metal, it is neceſſary to pour but a ſmall quantity at a time. There are various methods of combining this granulated copper, or other ſmall pieces of copper, with the vapour of zinc. Calamine, which is an ore of zinc, is pounded, and

* As the conſtruction of teleſcopes is foreign to the immediate purpoſe of this work, it has not been thought neceſſary to mention the ſeveral precautions of Mr. Edwards in this buſineſs: but the curious operator, who may wiſh to undertake the conſtruction of a reflecting teleſcope (the better kinds of which are not only difficult to be procured, but of conſiderable price), may have recourſe to Edwards's Treatiſe, annexed to the Nautical Almanack for 1787; where he will find ample inſtructions for that purpoſe.

mixed

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The fabrication of brafs.

mixed with the divided copper, together with a portion of charcoal. Thefe being expofed to the heat of a wind furnace, the zinc becomes revived, rifes in vapour, and combines with the copper, which it converts into brafs. The heat muft be continued for a greater or lefs number of hours, according to the thicknefs of the pieces of copper, and other circumftances; and at the end of the procefs the heat, being fuddenly raifed, caufes the brafs to melt, and occupy the lower part of the crucible. The moft fcientific method of making brafs feems to be that mentioned by Cramer *. The powdered calamine, being mixed with an equal quantity of charcoal, and a portion of clay, is to be rammed into a melting veffel; and a quantity of copper, amounting to two thirds of the weight of the calamine, muft be placed on the top, and covered with charcoal. By this management the volatile zinc afcends, and converts the copper into brafs, which flows upon the rammed clay: confequently, if the calamine contain lead, or any other metal, it will not enter into the brafs, the zinc alone being raifed by the heat.

Leaf brafs, or Dutch gold.

A fine kind of brafs, which is fuppofed to be made by cementation of copper plates with calamine, is hammered out into leaves in Germany; and is fold very cheap in this country, under the name of Dutch gold. It is, as I find, about five times as thick as gold leaf; that is to fay, it is about one fixty-thoufandth of an inch thick.

* Art of Affaying Metals. London, 1764. Page 377.

If

If brafs be kept in a ftate of ignition, with contact of air, the zinc burns, and the copper remains. Whether the zinc would quit the brafs without combuftion, is not known; though there is little doubt but it might be driven off in clofe veffels.

Metallic mixtures.

The quantity of zinc in good brafs is about one third of its weight.

Copper unites readily with regulus of antimony; and affords a compound of a beautiful violet colour. It does not readily unite with manganefe. With wolfram it forms a dark brown fpongy alloy, which is fomewhat ductile.

Native copper, and its ores.

Copper is either found native, moftly in an impure ftate; or in the form of a calx, of a red, green, or blue colour. The native folutions of copper frequently impregnate calcareous earths, in which they depofit the metal. The turquoife ftone is the tooth of an animal, penetrated with the blue calx of copper. Many ores of copper contain fulphur. Among thefe, the vitreous copper ore is of a red, brown, blue, or violet colour; fometimes cryftallized, but ufually foft enough to be cut with a knife. Some of the pyrites contain a confiderable proportion of copper, together with iron, fulphur, and clay. The grey copper ore is a fulphureous combination, containing arfenic: it is of a white, grey, or brown colour, heavy, and difficult of fufion. Blendofe copper ore is of a brown colour, hard, folid, compact, and granulated: it contains the metal, with fulphur, arfenic, zinc, and iron. Some flates, and one fpecies of coal, afford copper; and

 feveral

COPPER.

ſeveral waters contain this metal, diſſolved in vitriolic or marine acid.

Aſſay of native copper:

Native copper may be aſſayed in the humid way by ſolution in nitrous acid. If it contain gold, this metal falls untouched to the bottom, in the form of a black powder; if ſilver, it is ſoon precipitated by more copper; if iron, by boiling the ſolution for ſome time, it is gradually calcined, and falls to the bottom.

— of calciform ores:

The calciform copper ores are ſoluble in acids, and may be precipitated either by iron, which affords the copper in the metallic ſtate; or by mild alkali, which throws down 194 grains of precipitate for every 100 grains of copper.

— of ſulphureous ores:

Sulphureous copper ores may be powdered, and gently boiled to dryneſs in five times their weight of concentrated vitriolic acid. The whole, or moſt part of the ſulphur, flies off by this heat. The vitriolic ſalt of copper requires at leaſt four times its weight of water to diſſolve it. A ſufficient quantity being therefore added, and a poliſhed iron plate boiled in the ſolution, the copper will be precipitated. If iron be found to be mixed with the precipitate, it muſt be again diſſolved, to obtain a richer ſolution. This will depoſit pure copper, if the operation be conducted as before. If it contain other metals, they may be eaſily ſeparated by ſolution in nitrous acid.

— in the dry way.

In the dry way, the ſulphureous ores of copper muſt be firſt pulverized, and ſeparated as much as poſſible from the earthy and ſtony particles; then roaſted,

roaſted, to ſeparate the ſulphur and arſenic; and, laſtly, melted with an equal weight of M. Tillet's flux, which conſiſts of two parts of pounded glaſs, one calcined borax, and $\frac{1}{8}$ of charcoal. More borax may be added if the ore be poor. Alkaline fluxes are hurtful in the fuſion of copper ores, becauſe the ſalt combines with the ſulphur, and forms hepar, which diſſolves part of the copper.

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Treatment of copper ores in the large way.

In the large way, copper is roaſted in a cloſe furnace, by a ſlow fire, to ſcorify the mixtures of iron, and other ſubſtances. By repeated fuſions with ſulphur and charcoal, the ſcorified metal riſes to the top, and is ſcummed off. The copper in the great Hungarian mines is ſaid to undergo fuſion fourteen times before it is fit for ſale. The roaſted ore in the iſle of Angleſey is deprived of its vitriolic ſalt by waſhing; and the copper is precipitated by means of old iron immerſed in the water. This precipitated copper is, however, but a ſmall proportion of the whole produce.

Countries where copper is found.

Copper is found in various parts of the world; in Spain, France, England, Norway, Hungary, Sweden, and elſewhere. The Japan copper is ſaid to be purer, and has a greater ſpecific gravity, than any other copper. The wire-drawers, who require copper of extraordinary ductility, uſe the Swediſh copper. The copper mines in England are exceedingly numerous and productive. Paris mountain, on the iſle of Angleſey, contains a bed of ore forty feet in thickneſs; and is ſaid to produce upwards of four thouſand tons of copper annually.

COPPER.

Copper applied to various ufes.

The ufes of this metal are too numerous to be diftinctly fpecified. It has for fome years paft been applied with great fuccefs and advantage, for fheathing the bottoms of fhips; and feveral builders have lately endeavoured to introduce it as a covering for houfes. It is the lighteft of all coverings; but whether it be more durable than flate, which is nearly as light, has not yet been afcertained by experience.

CHAP.

CHAP. VII.

CONCERNING IRON.

IRON.

Characters of iron.

IRON is a metal of a blueifh white colour, of confiderable hardnefs and elafticity; very malleable, exceedingly tenacious and ductile, and of a moderate fpecific gravity among metallic fubftances. It is much difpofed to ruft by the accefs of air, or the action of water, in the common temperature of the atmofphere. The appearance of prifmatic colours on its polifhed furface takes place long before ignition; and at fo low a temperature, that the flighteft coating of greafe is fufficient to prevent their appearance, by defending it from the contact of air. It may be ignited, or at leaft rendered fufficiently hot to fet fire to brimftone, by a quick fucceffion of blows with a hammer. When ftruck with a flint, or other hard ftone, it emits decrepitating ignited particles, fuch as can be obtained from no other metal by the fame means. Thefe particles are feldom larger than the two hundredth part of an inch in diameter; and, when examined by a magnifier, are found to be hollow, brittle, and of a greyifh colour, refembling the fcales of burned iron. This metal is eafily calcined by fire. A piece of iron wire, immerfed in a jar of vital air, being ignited at one end, will be entirely confumed by the fucceffive combuftion of its parts. It requires a moft intenfe heat to fufe it; on which account it can only be brought into the fhape of tools and uten-

IRON.

Characters of iron.

fils by hammering. This high degree of infufibility would deprive it of the moft valuable property of metals, namely, the uniting of fmaller maffes into one, if it did not poffefs another fingular and advantageous property, which is found in no other metal except platina; namely, that of welding. In a white heat iron appears as if covered with a kind of varnifh; and in this ftate, if two pieces be applied together, they will adhere, and may be perfectly united by forging. Iron is thought to be the only fubftance in nature which has the property of becoming magnetical. It is highly probable, from the great abundance of this metal, that all fubftances which exhibit magnetifm do contain iron; but it muft be confeffed that there remain many experiments to be made among the earths and powders which exhibit magnetical properties, before this negative propofition, which confines magnetifm to iron, can be admitted as proved.

Calcination of iron by water.

When iron is expofed to the action of pure water, it acquires weight by gradual calcination, and inflammable air efcapes: this is a very flow operation. But if the fteam of water be made to pafs through a red-hot gun-barrel, or through an ignited copper or glafs tube containing iron wire, the iron becomes converted into a calx; while inflammable air paffes out at the other end of the barrel. This capital experiment * may be accounted for according to the ancient and modern theories. In the ancient theory, it is fuppofed that the water has combined with the iron, and difengaged its phlogifton in the

Ancient theory.

* Of M. Lavoifier.

form

IRON.

form of inflammable air; and confequently that, when this calx is again revived by heating a portion of it in inflammable air with a burning glafs, and water appears, at the fame time that part of the inflammable air is abforbed, the iron has imbibed phlogifton, and given out its water. Clear as this explanation appears to be, the folution afforded by the modern theory is not lefs perfpicuous. The maintainers of this theory reafon as follows: Iron has not been fhewn to be a compound fubftance; let us therefore confider it as a fimple fubftance, until we poffefs experiments which fhew the contrary. Water has been fhewn to be a compound fubftance, by the experiment of its production, by burning dephlogifticated and inflammable air together. We may fairly therefore affirm, that the inflammable air came from the water, in which we know it to exift; and that the vital air of the water, the peculiar inftrument of calcination, has combined with the iron. On the other hand, when the iron is revived in inflammable air, the water which appears is the very product of combination which was decompofed in the former inftance. For the vital air quits the iron to unite in the fluid ftate with the inflammable air; and the iron, being fet at liberty, recovers its original ftate; that is to fay, it is revived.

Calcination of iron by water.

Modern theory.

See page 95.

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That the iron, in the one inftance, attracts vital air from the water, and difengages inflammable air; and, in the other inftance, exhibits a lefs affinity with that fubftance, fo as to reftore it to its former combination; is a difficulty which, in the prefent ftate of our information, can only be accounted for by fuppofing,

Difficulty.

IRON. Calcination of iron by water.

poſing, that the temperature in the furnace differs from that produced by the burning glaſs; and that theſe affinities, like moſt others in chemiſtry, are not the ſame at all temperatures. This difficulty affects both theories alike; for it is not eaſier to account for the contrary tranſitions of water and phlogiſton, which mutually expel each other in the old theory, than for the tranſitions of dephlogiſticated and inflammable air in the new theory.

Theory.

The philoſophers who reject phlogiſton inſiſt, moreover, that the weight of the inflammable air produced, being deducted from the weight of the water made uſe of, leaves a quantity equal to the increaſe the iron gains by calcination; and that by burning the whole inflammable air produced, with a quantity of vital air equal in weight to the gain of the iron, a new quantity of water is recompoſed, which is equal likewiſe to that made uſe of. Hence they urge, that it is infinitely more probable that the inflammable air came from the water than from the iron. The latter fact, of the recompoſition, is in their favour; but the former is not. For whatever the inflammable air comes from, the firſt equation will be true; that is to ſay, if the iron give out phlogiſton, and receive water, its acceſſion of weight will be equal to the difference between the water it has received, and the phlogiſton it has loſt; but the reproduction of the water loſt will ſhew that the inflammable air really correſponds with the quantity required to form* ſo

* It may be urged that the two airs contain much water; and for that, as well as other reaſons, their abſolute quantities cannot

ſo much water, if we admit the accuracy of the experiments.

Solution of iron in the vitriolic acid.

The concentrated vitriolic acid ſcarcely acts on iron, unleſs it be boiling. When the acid is diſtilled to dryneſs from this metal, the retort is found to contain ſublimed flowers of ſulphur, and a white vitriolic maſs, partly ſoluble in water: the product which comes over is volatile vitriolic acid, and vitriolic acid air. If the vitriolic acid be diluted with two or three parts of water, it diſſolves iron readily, without the aſſiſtance of any other heat than is produced by the act of combination. During this ſolution, inflammable air eſcapes in large quantities. If heat be applied, the acid proceeds to diſſolve more iron, and depoſits a white ſaline maſs, or pale vitriol of iron.

Martial vitriol.

The combination of vitriolic acid and iron, called martial vitriol, is much more ſoluble in hot than cold water; and therefore cryſtallizes by cooling, as well as by evaporation. The cryſtals are effloreſcent, and

cannot be aſcertained. But it is not required to aſcertain their abſolute quantities: for it is enough if the two airs in this recompoſition be exactly in the ſame ſtate as in the original experiment, by which the component parts of water were determined. If a certain portion of water be neceſſary to inflammable air in the elaſtic ſtate, it muſt of courſe take it from the ſteam in the gun-barrel at the inſtant of its extrication, and not afterwards from the water of the receivers: this requires to be confirmed by an experiment over mercury. How far Dr. Prieſtley's experiments (Phil. Tranſ. lxxviii. and lxxix.) may affect the poſition, that water is a compound ſubſtance, cannot be clearly aſcertained until it is ſhewn that the acid produced in burning the two airs does not ariſe from impurity in one or both of them. See page 95.

IRON.

Martial vitriol.

fall into a white powder by expofure to a dry air, the iron becoming more calcined than before. A folution of martial vitriol, expofed to the air, imbibes its vital part; and a portion of the iron, becoming too much calcined to adhere to the acid, falls to the bottom in the form of ochre. The folution, as well as the cryftals it affords by evaporation, are thus rendered paler than before.

Page 140,

Martial vitriol is not made in the direct way, becaufe it can be obtained at lefs charge from the decompofition of martial pyrites.

Theory of the effects of vitriolic acid upon iron; according to the doctrine of phlogifton.

The different appearances which accompany the folutions of iron in the vitriolic acid, may be accounted for according to the principles either of the ancient or modern theories. In the ancient theory, iron being fuppofed to contain phlogifton, or the principle of inflammability, is calcined in both cafes; that is to fay, it gives out phlogifton *. With the concentrated acid the folution does not take place; becaufe the capacity of the mixture for heat, and confequently its abfolute quantity of heat, is too fmall to fupply what the increafed capacity of the vitriolic acid air would require, and confequently the iron is not decompofed. But when heat is applied, the phlogifton of the iron, uniting with the bafis of part of the acid, forms fulphur; which, together with another portion of the acid, rifes in the form of vitriolic acid air; at the fame time that the vital air of the decompofed acid unites with the calx of iron, which becomes foluble

* Kirwan, in Philof. Tranfact. vol. lxxii; and Effay on Phlogifton, London, 1789, page 62, or page 28 of the old edition.

in the acid that remains: but when much water is present, as in the diluted acid, the heat is supplied from the great capacity of the water; the phlogiston of the iron assumes the elastic form; and inflammable air flies off, while the acid unites with the calx of iron, and forms vitriol. The decomposition of the acid in the former, and not in the latter case, is accounted for from its strong attraction to the water. A considerable heat, applied with the diluted acid, calcines the iron more perfectly; which then either enters into the composition of pale vitriol, containing a larger proportion of acid, or falls down in the form of calx. The access of air does the same thing more gradually.

Theory:

In the antiphlogistic theory, iron is assumed to be a simple substance; vitriolic acid is said to be composed of vital air and sulphur; and water is admitted to be decomposable. When iron therefore is applied to concentrated vitriolic acid, the principles retain their order of combination at a common temperature; but as soon as the temperature is raised, the iron becomes calcined, by attracting vital air from part of the acid, whose sulphur is therefore set at liberty, and flies off with another portion of the acid, in the form of vitriolic air; while the remaining acid combines with part of the calx. But when the acid is more diluted, the water itself is decomposed; its inflammable air is disengaged; its vital air unites with and calcines the iron; and the vitriolic acid dissolves the calx.

— according to the antiphlogistic doctrine.

The necessity of heat being applied to the concentrated solution in the one case rather than the other, may be referred to the capacities of the bodies, before and

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Theory of the action of vitriolic acid on iron.

and after the change, in either theory. But it muſt be confeſſed that the cauſe of the diſengagement of vitriolic air in the one caſe, and inflammable in the other, is not ſo well ſolved. It has not been explained, upon the old theory, why the phlogiſton in one caſe unites with the acid, and forms ſulphur, and in the other flies off alone; neither has it been ſhewn, in the new theory, why the water ſhould not be decompoſed in the former inſtance, as well as the latter.

The further calcination of the iron by heat, or by expoſure of the ſolution to the air, is accounted for, in the new theory, from the abſorption of more vital air. The general fact, that a definite degree of calcination is neceſſary for the moſt perfect ſolution of metals in acids, depends on attractions which have not been experimentally reſolved; but which, in the way of conjecture, may be as eaſily accounted for by one theory as by the other.

Precipitates of iron.

Vitriol of iron is decompoſed by alkalis and by lime. Cauſtic fixed alkali precipitates the iron in deep green flocks, which are diſſolved by the addition of more alkali, and form a red tincture. The mild alkali does not rediſſolve the precipitate it throws down, which is of a greeniſh white colour. Diſtillation ſeparates the acid from martial vitriol, and leaves the brown calx of iron, called colcothar.

Colcothar.

Black fecula, precipitated by aſtringents.

Vegetable aſtringent matters, ſuch as nut-galls, the huſks of nuts, logwood, tea, &c. which contain the acid of galls hereafter to be deſcribed, precipitate a fine black fecula from martial vitriol, which remains ſuſpended for a conſiderable time in the fluid, by the addition of gum arabic. This fluid is well known by the

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Ink; its nature doubtful.

he name of ink. It appears to consist of the acid of galls, united to the calx of iron: but its nature has ot been well determined; more especially by an examination of the contents of the fluid which remains fter the precipitate has been completely deposited. The black fecula is not magnetical; but it is conerted into a brown magnetic calx by heat. An exess of either of the three ancient mineral acids reners ink colourless; but the acetous acid, or vinegar, oes not. Ink becomes blacker by exposure to the ir, which acidifies more completely the principle ombined with the iron; but ancient writings become ore and more yellow, in consequence of the escape f the acid *. Their legibility may be restored by the ddition of infusion of galls, or gallic acid. The best ethod of restoring the legibility of ancient writ-

* Inks seem to fail chiefly on account of the small proportion d destructibility of the astringent principle, or gallic acid. Dr. ewis recommends the following receipt for writing-ink (Comerce of Arts, page 391): One part martial vitriol, one part owdered logwood, and three parts powdered galls, are to be fused in one quart of vinegar, or white wine, or water, for ch ounce of the vitriol, together with one ounce of gum arac for each quart of the liquor; and shaken for four or five nes a day, during ten or twelve days: after which it may be canted for use.

On the above I must remark, that though vinegar affords a good ack ink, yet Dr. Lewis has overlooked a great inconvenience tending its use. It acts so strongly upon the quills, that the arpness of the extremity of a pen used with this ink soon es off, and continually wants mending. A perfect theory of k would probably lead to great improvements in this most eful fluid.

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ings * confifts in fpreading a folution of the Pruffian alkali thinly with a feather over the traces of the letters; and then to touch it gently, and as nearly upon or over the letters as can be done, with a diluted acid, by means of a pointed ftick.

Manufacture of Pruffian blue.

The beautiful pigment, well known in the arts by the name of Pruffian blue, is likewife a precipitate afforded by martial vitriol. It has been made for confiderably more than half a century; but its compofition is not yet clearly afcertained. The procefs for making it is as follows: Calcine a mixture of equal parts of vegetable alkali and dried bullocks blood, until it ceafes to emit either flame or fmoke; then raife the fire, to give the mafs a low red heat. Throw the matter while red-hot into as many quarts of water as there were pounds of the original mixture, and boil it for half an hour. Decant the liquid, and wafh the coaly refidue with more water, till it comes off almoft infipid. Add this water to the former, and evaporate the whole by boiling, until it be reduced again to the former number of quarts. This is the lixivium fanguinis, or Pruffian alkali; which, if added in a proper quantity to a folution of iron, precipitates it partly in the form of calx, and partly in the form of Pruffian blue. If the marine acid be added to the precipitate, it diffolves the calciform part, and leaves the Pruffian blue much purer. Hence it appears that the whole of the alkali, in the ufual method of calcination with bullocks blood, or other animal fubftances, is not faturated with the colouring matter, but

Pruffian alkali.

* Blagden, in Philof. Tranf. vol. lxxv. page 455.

that

hat the unſaturated part of the alkali precipitates part of the iron in the calciform ſtate; while the other part, combining with the colouring matter, falls down n the form of Pruſſian blue. For chemical purpoſes, he Pruſſian lye is produced, by boiling the alkali upon Pruſſian blue ready formed. The calx of iron is thus deprived of the colouring matter by the alkali, to which it has a greater affinity, and which it only quits when there is another acid preſent to unite with the lkali; as in the juſt-mentioned inſtance of the ſolution of iron, where a double affinity takes place. The Pruſſian alkali, prepared in either way, contains ſome ron. It can be had pure in no other way than by irectly combining the pure colouring matter with a ure alkali.

Pruſſian alkali made for chemical purpoſes.

The habitudes of this colouring matter denote it o be an acid. If the Pruſſian alkali be boiled in a etort with weak vitriolic acid, the colouring matter omes over in the form of an inflammable air, which vill be abſorbed by water placed in the receiver. As a portion of vitriolic acid likewiſe comes over, a econd diſtillation is neceſſary to be made, with the ddition of chalk. The vitriolic acid, by this means orming ſelenite, is detained; while the Pruſſian acid aſſes over totally before one-fourth of the water is iſtilled off.

Acid of Pruſſian blue.

The colouring matter of Pruſſian blue is not only eized by the fixed alkalis, but likewiſe by the volatile lkali, by lime, by magneſia, and by ponderous earth; vith which it forms peculiar compounds, capable of recipitating Pruſſian blue, by double affinity, from the olutions of iron in acids. Various metals likewiſe com-

Combinations of Pruſſian acid.

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Caution in using proof liquors.

combine with it. Alkalis, or lime, combined with the Pruſſian acid, are uſed as teſts to aſcertain the preſence and quantity of iron in ſolution. But all the alkaline or earthy combinations, produced by applying thoſe ſubſtances to Pruſſian blue, contain iron, which falls down in the form of the blue precipitate when an acid is added. For this reaſon they cannot be uſed in accurate experiments, unleſs a previous trial has been made of the quantity a known proportion of the proof liquor is capable of precipitating.

Experiments on Pruſſian acid.

If the dephlogiſticated or aërated marine acid be mixed with the Pruſſian acid, the former reſumes the ſtate of common marine acid; while the latter acquires a much ſtronger ſmell, and appears to be more volatile. In this ſituation it does not form Pruſſian blue with the ſolutions of iron; but affords a green precipitate, which becomes blue by expoſure to the light, or by the addition of volatile vitriolic acid.

If martial vitriol be added to the dephlogiſticated or aërated marine acid, and a ſolution of Pruſſian alkali be poured in, the green precipitate which is formed is again diſſolved; but it may be precipitated of a blue colour by the addition of volatile vitriolic acid, or martial vitriol, or iron alone.

Theory.

In the inſtances laſt mentioned we may perceive that the effects depend on the dephlogiſtication or addition of vital air to the Pruſſian acid, accordingly as we adopt the ancient or the modern theory. The green precipitate, which may be conſidered either as dephlogiſticated Pruſſian blue, or as Pruſſian blue combined with vital air, becomes common Pruſſian blue

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blue by the action of light; which, as we have frequently had occasion to remark, operates in many instances in a manner contrary to that of combustion; that is to say, it either adds phlogiston, or expels vital air, or does both. By this action therefore the Prussian blue returns to its original state. The addition of volatile vitriolic acid must produce a like effect; for this acid is phlogisticated according to the old theory, or is deficient in vital air according to the new: it is therefore disposed either to phlogisticate the green precipitate, or to attract vital air from it; which is all that it requires to convert it into common Prussian blue. The same theories manifestly apply to the green precipitate, which is redissolved; for in whatever state of combination it may be supposed to remain, as to the order or arrangement of the principles which are united in the fluid, the addition of volatile vitriolic acid, or common vitriol, or iron in the metallic state, will impart phlogiston, or attract vital air; the absence of the one, or redundance of the other of which, is supposed, according to the respective theories, to cause the difference between it and Prussian blue.

Theory of the effects of aerated marine acid on Prussian acid.

If the Prussian acid be impregnated more strongly with the dephlogisticated or aërated marine acid, and then exposed to the action of light, it assumes new properties. It no longer combines with iron precipitated from its solutions; its smell is entirely different from that which it before possessed; and now resembles an aromatic oil, the greatest part of it separating from the water, at the bottom of which it flows in the form of an oil. This fluid however is not inflam-

Experiment.

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mable. By a gentle heat it rifes in the form of a vapour, not foluble in water: and in time it affumes the form of fmall cryftals. Pruffian acid cannot be reftored after it has undergone thefe changes. Their theory is not known.

Difcovery of the component parts of Pruffian acid.

Various experiments have been made to difcover the component parts of the Pruffian acid. If equal parts of pulverized charcoal and vegetable alkali be made red-hot for a quarter of an hour in a crucible, and fome fal ammoniac in fmall pieces be then brifkly ftirred down into the mafs, the ammoniacal vapours will foon ceafe. The ignited matter being then thrown into water, affords a lixivium equal to the beft which is made with blood. From thefe, and other experiments, it was concluded that its component parts are fixed air, volatile alkali, and the principle of inflammability, or phlogifton. Later experiments appear to have decided the queftion fomewhat more accurately. When the acid has been converted, by means of the dephlogifticated or aërated marine acid, into that ftate which affords a green precipitate with iron, it emits alkaline air upon the addition of lime, or a pure alkali. If the lime, or alkali, be afterwards faturated by the addition of fome other acid, the Pruffian acid is not difengaged, or reftored, but is no where found; hence it follows, that the alkaline air was one of the principles of the Pruffian acid, which is deftroyed: and as the lime or alkali ufed in this decompofition is found to be in a mild ftate, that is to fay, combined with fixed air, though it did not contain that fubftance before; it is clear that the other principle of the Pruffian acid is fixed air.

The

Component parts of Pruſſian acid.

The common Pruſſian acid conſiſts therefore of volatile alkali, united with the baſe of fixed air, or that ſubſtance which, in combination with vital air, forms the acid called fixed air. When the Pruſſian acid receives vital air, and is converted into the ſtate proper to afford the green precipitate, it then appears to conſiſt of the ſame principles as the mild or concrete volatile alkali, though probably in a different order of combination; and this order ſeems to be deranged by the addition of the lime, or the fixed alkali, which attracts thoſe principles that form fixed air, at the ſame time that the principles which form volatile alkali fly off in the elaſtic ſtate.

The component parts of Pruſſian acid will conſequently be phlogiſticated air, inflammable air, and fixed air, or its baſe; all which are afforded by animal ſubſtances: but they do not form this peculiar combination in any caſe yet known, excepting that in which an alkali is preſent when thoſe ſubſtances are decompoſed by fire *.

Action of nitrous acid on iron.

Concentrated nitrous acid acts very ſtrongly upon iron filings, much nitrous air being diſengaged at the ſame time. The ſolution is of a reddiſh brown, and depoſits the calx of iron after a certain time; more eſpecially if the veſſel be left expoſed to the air. A diluted nitrous acid affords a more permanent ſolution

* For a fuller account of this ſubject conſult Scheele's Eſſays; the Opuſcula, or Chemical Eſſays, of Bergman; and the Annales de Chimie, vol. i; the latter of which contains an abſtract of a valuable memoir of Berthollet, read before the Royal Academy of Sciences at Paris, in the year 1787.

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of iron, of a greenifh colour, or fometimes of a yellow colour: neither of the folutions affords cryftals; but they depofit the calx of iron by boiling, at the fame time that the fluid affumes a gelatinous appearance. This magma, by diftillation, affords fuming nitrous acid, much nitrous air, and fome phlogifticated air; a red calx being left behind, which, in all probability, retains moft of the vital air of the acid.

Precipitates of iron from nitrous acid.

If vegetable alkali be added to the nitrous folution of iron, a brown precipitate falls down; of which a fmall quantity is rediffolved by the alkali. Mild vegetable alkali feparates a yellowifh calx, which foon becomes of a beautiful orange red colour. If the mixture be agitated during the effervefcence, the precipitate is rediffolved in much greater quantity than by the pure vegetable alkali; doubtlefs by the medium of the fixed air. This folution is known by the name of Stahl's martial alkaline tincture, and is of a fine red colour, which however is impaired by time. Pure volatile alkali feparates a deep green and almoft black precipitate from the nitrous folution of iron. The mild volatile alkali rediffolves the iron, which it feparates from the acid; and forms an alkaline tincture of a more lively colour than that of Stahl.

Martial alkaline tinctures.

Action of marine acid on iron.

Diluted marine acid rapidly diffolves iron, at the fame time that a large quantity of inflammable air is difengaged, and the mixture becomes hot. In this, as well as in the vitriolic folution of iron, the fame quantity of alkali is faid to be required to faturate the acid as before the folution; whence it is inferred that the acid is not decompofed, but that the calcina-

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tion is effected by the vital air of the water: whence alfo it appears to follow, that the inflammable air muft be afforded from the decompofed water, and not from the metal. It muft however be remarked, that this fact, as well as moft of thofe upon which the rejection of phlogifton, or the inflammable principle, is grounded, are controverted by the philofophers who maintain the exiftence of that principle.

Marine folution of iron.

The marine folution of iron is of a yellowifh green colour, and is much more permanent than the folutions of that metal in the vitriolic or nitrous acids; though, like all the other folutions of iron, it depofits its metal by expofure to the air. By evaporation it affumes the confiftence of fyrup, in which needle-formed and deliquefcent cryftals appear. Some chemifts affirm, that the acid quits the iron by diftillation, though much more difficultly than either the nitrous or vitriolic acid; but this interefting experiment has not been made fince the improvements of chemiftry have led philofophers to attend to fuch products as appear in the permanently elaftic ftate.

Precipitates.

The marine folution of iron is decompofed by lime and by alkalis; but the precipitates are more eafily reduced to the metallic ftate than thofe afforded by other acids. Liver of fulphur, hepatic air, and aftringents, decompofe this, as well as the other folutions of iron; and the pure Pruffian alkali throws down a very fine blue precipitate.

Action of fixed air on iron:

Fixed air, diffolved in water, combines with a confiderable quantity of iron, in proportion to its mafs. Vinegar fcarcely diffolves it, unlefs by the affiftance of the air.

—and vinegar.

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Action of earths, &c. on iron.

In the dry way, this metal does not combine with earths, unlefs it be previoufly calcined; in which cafe it affifts their fufion, and imparts a green colour to the glafs. It appears to combine with alkalis by fufion. Nitre detonates ftrongly with it, and becomes alkalized. Sal ammoniac is decompofed by it. Two parts of iron filings, triturated with one part of fal ammoniac, and expofed to diftillation, afford about one part of liquid volatile alkali, contaminated by a fmall portion of iron. Some inflammable air comes over in this diftillation, either from the iron, or from the water contained in the fal ammoniac: the refidue confifts of iron, united to marine acid. A medical preparation is made by fubliming fal ammoniac from a fmall portion of iron filings; which gives part of the falt a yellow colour. The calx of iron decompofes fal ammoniac by feizing its acid, even in the cold.

Combination of iron with fulphur in the humid way.

Sulphur combines very readily with iron, in the dry, and even in the humid way, though neither of thefe fubftances is fcarcely at all foluble in water. A mixture of iron filings and flowers of fulphur being moiftened, or made into a pafte, with water, becomes hot, fwells, adheres together, breaks, and emits watery vapours of an hepatic fmell. If the mixture be confiderable in quantity, as for example, one hundred pounds, it takes fire in twenty or thirty hours, as foon as the aqueous vapours ceafe. This effect may be explained without difficulty in a general way, though the circumftances require to be more minutely examined:—Iron, fulphur, and water, are placed in contact. The iron is very fparingly foluble in water *;

Spontaneous inflammation.

* Annales de Chimie, vol. i. 220.

and

and the fulphur is probably foluble in a fmall degree, as may be judged by its becoming foft in that fluid. In the ancient theory, it may be faid that the fulphur combines with the calx of the iron, and expels its inflammable air or phlogifton. The heat muft be deduced, in any theory, from the change of capacity, or rapid commotion, produced in the act of union. This heat volatilizes part of the fulphur, together with the inflammable air; and if the temperature be fufficiently elevated, thefe fubftances will take fire, at the moment of their extrication, by the affiftance of the air of the atmofphere. In the new theory, the explanation will be nearly the fame. The iron and the fulphur, being confidered as fimple fubftances, tend to combine with each other, through the medium of vital air, which calcines the iron, and is fuppofed to be afforded by decompofition of the water. The fame decompofition extricates inflammable air from the water. This, together with the fulphur, forms hepatic air; which, flying off at the temperature of ignition, takes fire by combination with the air of the atmofphere. In this theory it may further be added, that, as fulphur and water, in contact, at an elevated temperature, afford inflammable air, which is explained by the fuppofition of vital air combining with the fulphur, there would be an increafe of inflammation from this caufe. Some doubt however may be entertained, whether fulphur be more combuftible than inflammable air at any temperature, fince hepatic air depofits fulphur when detonated with vital air; which muft, in all probability, depend on the latter being lefs combuftible at the temperature of inflammation. On the

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Theory of the inflammation of iron and fulphur:

— by the antiphlogiftic hypothefis.

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whole it appears, that facts and obfervations are wanting, rather than probable theories; and that it is fcarcely neceffary to purfue this inquiry more minutely in the way of argumentative difquifition. The fpontaneous combuftion of iron and fulphur with water, is evidently an effect of the fame kind as the decompofition of pyrites.

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Union of fulphur with iron in the dry way.

Sulphur combines very readily with iron by fufion; and produces a compound of the fame nature as the pyrites, and exhibiting the fame radiated ftructure when broken. If a bar of iron be heated to whitenefs, and then touched with a roll of fulphur, the two fubftances combine, and drop down together in the fluid ftate. It is neceffary that this experiment fhould be made in a place where there is a current of air to carry off the fumes; and the melted matter, which may be received in a veffel of water, is of the fame nature as that produced by fufion in the common way, excepting that a greater quantity of fulphur is fufed by the contact of the bar of iron. The experiment of combining iron and fulphur together by fufion, has not been made with an attention to the volatile products, if any be extricated. As neither of thefe fubftances contains water, and both are fuppofed, in the new theory, to be fimple bodies, the experiment might, perhaps, afford an interefting refult.

Phofphorus and iron.

If equal parts of phofphoric glafs, and iron clippings, together with one-fixteenth of a part of pulverized charcoal, be fufed together, the mixture is very brittle, white in its fracture, and of a ftriated and granulated texture. This combination of iron with phof-

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phofphoric acid is found in the iron produced from bog ores, which abound in the remains of decayed vegetables. It is the caufe of brittlenefs in the iron when cold; which occafions that kind of iron to be called cold fhort iron by the workmen. Phofphorated iron was at firft taken to be a peculiar metal; and was called fiderite by Bergman.

Cold fhort iron.

Siderite.

Iron unites with gold, filver, and platina. When heated to a white heat, and plunged in mercury, it becomes covered with a coating of that metal. Long trituration of mercurial amalgams likewife caufes a coating to adhere to the ends of iron peftles; and fmall fteel fprings, kept plunged beneath the furface of mercury in certain barometers, have become brittle in procefs of time: hence there appears to be a weak action between mercury and iron. Iron and tin very readily unite together; as is feen in the art of tinning iron veffels, and in the fabrication of thofe ufeful plates of iron, coated with tin, which are generally diftinguifhed by the fimple name of tin alone. The chief art of applying thefe coatings of tin confifts in defending the metals from calcination by the accefs of air. After the iron plates are fcraped, or rendered very clean by fcouring with an acid, they are wetted with a folution of fal ammoniac, and plunged into a veffel containing melted tin; the furface of which is covered with pitch or tallow, to preferve it from calcination. The tin adheres to and intimately combines with the iron to a certain depth, which renders the tinned plates lefs difpofed to harden by hammering, than before, as well as much lefs difpofed to alter, by the united action of air and moifture. The procefs for

Metallic combinations.

Tinning of iron plates.

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Combinations of iron with metallic ſubſtances.

for tinning of iron veſſels does not eſſentially differ from that which has already been deſcribed of copper veſſels. Iron does not unite with biſmuth, at leaſt in the direct way. As nickel cannot be purified from iron without the greateſt difficulty, it may be preſumed that theſe ſubſtances would readily unite, if the extreme infuſibility of both did not preſent an obſtacle to the chemical operator. Arſenic forms a brittle ſubſtance in its combination with iron. This ſemi-metal, which is ſo abundant in the mineral kingdom, is ſaid to be the cauſe of the brittleneſs which ſome ſpecimens of iron poſſeſs when hot, though malleable when cold. Iron, thus contaminated, is diſtinguiſhed by workmen by the name of red ſhort iron. Cobalt forms a hard mixture with iron, which is not eaſily broken. The inflammability and volatility of zinc preſent an obſtacle to its combination with iron. It is not improbable, however, but that clean iron filings would unite with zinc, if that metal were kept in contact with them for a certain time, in a heat not ſufficient to cauſe it to riſe; for it has been found that zinc may be uſed in the operation of coating iron in the ſame manner as tin. Antimony unites with iron, and forms a hard brittle combination, which yields, in a ſlight degree, to the hammer. The combination of ſulphur, and the regulus of antimony, which is commonly known by the name of antimony, is decompoſed by virtue of the greater affinity of the iron to the ſulphur. For this purpoſe, five ounces of the points of nails from the farriers may be made red hot in a crucible; one pound of pulverized ore of antimony muſt then be thrown into the crucible, and

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the heat quickly raifed to fufe the whole. When the fufion is perfect, an ounce of nitre in powder may be thrown in, to facilitate the feparation of the fcoriæ. After the mafs is cooled, the antimony is found feparate at the bottom of the crucible, while the iron remains in combination with the fulphur and alkali. If the proportion of the iron be confiderably greater than five ounces to the pound of antimonial mineral, the regulus will be alloyed with iron. Manganefe is almoft always united with iron in the native ftate. Wolfram forms a brittle whitifh-brown hard alloy, of a compact texture, when fufed with white crude iron.

Combinations of iron with metallic fubftances.

The habitudes of iron with the regulus of molybdena are not known.

Native iron and its ores.

Iron is the moft diffufed, and moft abundant, of metallic fubftances. Few mineral bodies, or ftones, are without an admixture of this metal. Sands, clays, and the waters of rivers, fprings, rain, or fnow, are fcarcely ever perfectly free from it. The parts of animal and vegetable fubftances likewife afford iron in the refidues they leave after incineration. It has been found native, in large maffes, in Siberia *, and in the internal parts of South America. This metal however in its native ftate is fcarce: moft iron is found in the calciform ftate, in ochres, bog ores, and other friable earthy fubftances, of a red, brown, yellow, or black colour. The hæmatites, or blood ftones, are likewife calciform ores of iron: thefe are either of a red colour, or blue, yellow, or brown. This ufeful

* See Bergman's Effays; Magellan's improved edition of Cronftedt's Mineralogy; and the Philof. Tranf. lxxviii. 37.

metal

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Ores of iron.

metal is fo abundant, that whole mountains are compofed of iron ftone; whereas, other metals ufually run in fmall veins. Befides the calciform ores of iron, which are either nearly pure, or elfe mixed with earths, as in fpars, jafper, boles, bafaltes, &c. iron is mineralized with fulphur, as in the pyrites; with arfenic, in the white pyrites; or with both. An iron ore is likewife found, of a blue colour, and powdery appearance, which is thought to be of the fame nature as Pruffian blue. The coaly iron ores contain bitumen. The magnet, or loadftone, is an iron ore, whofe conftitution has not yet been accurately examined. Iron is alfo found in combination with the vitriolic acid, either diffolved in water, or in the form of vitriol.

Humid analyfis of iron ores.

To analyfe the ores of iron in the humid way, they muft be reduced to a very fubtle powder, and repeatedly boiled in marine acid. If the fulphureous ores fhould prove flow of folution, a fmall quantity of nitrous acid muft be added to accelerate the operation. The iron being thus extracted, the infoluble part of the matrix only will remain. Pruffian alkali, being added to the decanted folution, will precipitate the iron in the form of Pruffian blue. This precipitate, when wafhed and dried, will be equal in weight to fix times the quantity of metallic iron it contains; and from this iron four parts in the hundred muft be deducted, to allow for the iron which is contained in the Pruffian alkali itfelf. But as this alkali, and every other preparation containing the Pruffian acid, does not conftantly afford the fame quantity of iron, the moft exact way, in the ufe of fuch preparations, confifts

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consists in previously dissolving a known quantity of iron in vitriolic acid; and precipitating the whole by the addition of the Prussian alkali. This result will afford a rule for the use of the same alkali in other solutions. For as the weight of the precipitate obtained in the trial experiment, is to the quantity of iron which was dissolved and precipitated; so is the weight of the precipitate obtained from any other solution, to the quantity of iron sought.

If the iron be united to any considerable proportion of zinc or manganese, the Prussian blue must be calcined to redness, and treated with pale nitrous acid, which will take up the calx of zinc. The manganese may then be dissolved by nitrous acid, with the addition of sugar; and the remaining iron being dissolved by marine acid, and precipitated by mild mineral alkali, will afford 225 grains of precipitate for every 100 grains of metallic iron.

Analysis in the dry way.

To examine the ores of iron in the dry way, the only requisite is fusion, in contact with charcoal. For this purpose, eight parts of pulverized glass, one of calcined borax, and half a part of charcoal, are to be well mixed together. Two or three parts of this flux, being mixed with one of the pounded ore, and placed in a crucible, lined with a mixture of a little clay and pounded charcoal, with a cover luted on, is to be urged with the strong heat of a smith's forge for half an hour. The weight of the ore, in this experiment, should not exceed 60 grains. Other processes for determining the contents, or metallic product, of iron ores, are instituted by performing the same ope-

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rations in the ſmall, as are intended to be uſed in the large way.

Smelting of iron in the large way.

In the large iron works, it is uſual to roaſt, or calcine the ores of iron, previous to their fuſion; as well for the purpoſe of expelling ſulphureous or arſenical parts, as to render them more eaſily broken into fragments of a convenient ſize for melting. The mineral is melted, or run down, in large furnaces, from 16 to 30 feet high; and variouſly ſhaped, either conical or elliptical, according to the opinion of the iron maſter. Near the bottom of the furnace is an aperture for the inſertion of the pipe of large bellows, worked by water or ſteam, or of other machines for producing a current of air; and there are alſo holes at proper parts of the edifice, to be occaſionally opened, to permit the ſcoriæ and the metal to flow out, as the proceſs may require. Charcoal, or coke, with lighted bruſhwood, is firſt thrown in; and when the whole inſide of the furnace has acquired a ſtrong ignition, the ore is thrown in by ſmall quantities at a time, with more of the fuel, and commonly a portion of limeſtone, as a flux: the ore gradually ſubſides into the hotteſt part of the furnace, where it becomes fuſed; the earthy part being converted into a kind of glaſs; while the metallic part is reduced by the coal, and falls through the vitreous matter to the loweſt place. The quantity of fuel, the additions, and the heat, muſt be regulated, in order to obtain iron of any deſired quality; and this quality muſt likewiſe, in the firſt product, be neceſſarily different, according to the nature of the parts which compoſe the ore.

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IRON. States of iron. The three kinds of crude iron.

The iron which is obtained from the ſmelting furnaces is not pure; and may be diſtinguiſhed into three ſtates:—white crude iron, which is brilliant in its fracture, and exhibits a cryſtallized texture, more brittle than the other kinds, not at all malleable, and ſo hard as perfectly to withſtand the file: grey crude iron, which exhibits a granulated and dull texture when broken; this ſubſtance is not ſo hard and brittle as the former, and is uſed in the fabrication of artillery, and other articles which require to be bored, turned, or repaired: and black caſt iron, which is ſtill rougher in its fracture; its parts adhere together leſs perfectly than thoſe of the grey crude iron: this is uſually fuſed again with the white crude iron.

Refining of iron.

Whenever crude iron, eſpecially the grey ſort, is fuſed again with contact of air, it emits ſparkles, loſes weight, and becomes leſs brittle. In order to convert it into malleable iron, it is placed on a hearth, in the midſt of charcoal, urged by the wind of two pair of bellows. As ſoon as it becomes fuſed, a workman continually ſtirs it with a long iron inſtrument. During the courſe of ſeveral hours it becomes gradually leſs fuſible, and aſſumes the conſiſtence of paſte. In this ſtate it is carried to a large hammer, the repeated blows of which drive out all the parts that ſtill partake of the nature of crude iron ſo much as to retain the fluid ſtate. By repeated heating and hammering more of the fuſible iron is forced out; and the remainder, being malleable, is formed into a bar, or other form, for ſale. Crude iron loſes upwards of one-fourth of its weight in the proceſs of refining.

Purified,

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Bar iron.

Purified, or bar iron, is soft, ductile, flexible, malleable, and possesses all the qualities which have been enumerated in this chapter, as belonging exclusively to iron. When a bar of iron is broken, its texture appears fibrous; a property which depends upon the mechanical action of the hammer, while the metal is cold. Ignition destroys this fibrous texture, and renders the iron more uniform throughout; but hammering restores it.

Iron converted into steel by cementation.

If the purest malleable iron be bedded in pounded charcoal, in a covered crucible, and kept for a certain number of hours in a strong red heat (which time must be longer or shorter, according to the greater or less thickness of the bars of iron), it is found that by this operation, which is called cementation, the iron has gained a small addition of weight, amounting to about the hundred and fiftieth, or the two hundredth part; and is remarkably changed in its properties. It is much more brittle and fusible than before. Its surface is commonly blistered when it comes out of the crucible; and it requires to be forged, to bring its parts together into a firm and continuous state. This cemented iron is called steel. It may be welded like bar iron; but its most useful and advantageous property is that of becoming extremely hard when ignited, and plunged in cold water. The hardness produced is greater in proportion as the steel is hotter, and the water colder. The colours which appear on the surface of steel slowly heated, are yellowish white, yellow, gold colour, purple, violet, deep blue, yellowish white; after which the ignition takes place. These signs direct the artist in tempering or reducing the

Hardening.

Tempering.

the hardneſs of ſteel to any determinate ſtandard. If ſteel be too hard, it will not be proper for tools which are intended to have a fine edge, becauſe it will be ſo brittle that the edge will ſoon become notched; if it be too ſoft, it is evident that the edge will bend or turn. Some artiſts ignite their tools, and plunge them in cold water; after which, they brighten the ſurface of the ſteel upon a ſtone: the tool being then laid upon charcoal, or upon the ſurface of melted lead, or placed in the flame of a candle, gradually acquires the deſired colour; at which inſtant they plunge it into water. Others, eſpecially in larger inſtruments, plunge the tool into very cold water as ſoon as it is completely ignited; and, when it ceaſes to be luminous beneath the water, they take it out, rub it quickly with a file, or on a plate covered with ſand, that it may acquire a white ſurface. The heat which the metal ſtill poſſeſſes ſoon begins to produce the ſucceſſion of colours. If a hard temper be deſired, the piece is dipped again, and ſtirred about in the cold water as ſoon as the yellow tinge appears. If the purple appear before the dipping, the temper will be fit for gravers, and tools uſed in working upon metals; if dipped while blue, it will be proper for ſprings, and for inſtruments uſed in the cutting of ſoft ſubſtances, ſuch as cork, leather, and the like; but if the laſt pale colour be waited for, the hardneſs of the ſteel will ſcarcely exceed that of iron. It is a circumſtance worthy of remark, that ſteel has a leſs ſpecific gravity when hardened than when ſoft; but there are no circumſtances, upon which a probable connection between theſe two properties, namely

The proceſſes for hardening and tempering of ſteel.

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the increafed hardnefs, and the diminifhed fpecific gravity, can be made out.

The ufual time required for the cementation of fteel, is from fix to ten hours. If the cementation be continued too long, the fteel becomes porous, brittle, of a darker fracture, more fufible, and incapable of being forged or welded. On the contrary, fteel cemented with earthy infufible powders, is gradually reduced to the ftate of forged iron again. Simple ignition produces the fame effect; but is attended with calcination of the furface. The texture of fteel is rendered more uniform by fufing it before it is made into bars: this is called caft fteel; and is rather more difficultly wrought than common fteel, becaufe it is more fufible, and is difperfed under the hammer if heated to a white heat.

Caft fteel.

Comparifon of fteel and crude iron.

When we confider the operations by which crude iron is brought into the malleable ftate, then converted into fteel, and afterwards into a fufible metal, which is not malleable; we may perceive that fteel-making is a kind of inverfion of the procefs of refining iron, as practifed in the firft inftance. When the calx of iron is mixed together in the fmelting furnace, with combuftible matter and glafs, it will either be completely or partially revived, according to the management of the procefs. Much of the coal will however be fo enveloped with the vitreous matter as to remain unburned: and the reduced iron, with which it may be in contact, will be in the fame fituation as forged iron in the cementing pot; that is to fay, it will be in contact with coal at a very elevated temperature, and defended from the air. From

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the great infufibility of iron, it may reafonably be concluded that the reduced metal does not flow into the bottom of the furnace, until the charcoal has converted it into a fufible matter fimilar to fteel, by the fame action which takes place in cementation, whatever that action may be. Hence it muft follow, that the various fpecimens of crude or caft iron will differ in their qualities, as well on account of the degree of cementation they have undergone, as the degree of reduction which has taken place among the metallic parts, which are carried down, and form the whole mafs. Since the coal, in the procefs of cementation, communicates or adds weight to the iron; and fince crude iron, as well as fteel, exhibits fparkles, and is more eafily burned than other iron: it may therefore be concluded that, in the procefs of refining, that part of the inflammable fubftance which had united with the metal is burned, and leaves the iron much lefs fufible than before. Stirring the mafs multiplies the contacts of the air with the burned fubftances; thefe furfaces of contact will therefore fucceffively afford thin coats of infufible metal. In this manner it is found, that if a large piece of crude iron be expofed to heat in a wind furnace, the external part will be deprived of its fufibility during the time required to produce a ftrong heat in the whole mafs; and the internal part will be melted, and run out, leaving the fhell behind. Iron which is of the confiftence of pafte may therefore be confidered, like any other pafte, as a mixture of a fluid with a folid. It will be eafily underftood that the forging will bring the parts of difficult fufion together, and extrude the lefs refined and

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Confideration of the effects of heat in refining iron.

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fluid parts: it will alſo be evident that this operation is not likely to drive out the whole of the fuſible matter. When the iron has arrived at that ſtate wherein the quantity of fibre or tough iron is ſufficient to anſwer the mechanical purpoſes to which it is intended to be applied, the artiſt will conſider it as ſufficiently refined; and the reſidue of fuſible iron contained in the bar anſwers, in all probability, the valuable purpoſe of connecting theſe infuſible maſſes together. Thus we find that forged iron appears as if covered with a varniſh, when urged to a white heat; we find that this varniſh is more abundant in ſteel; and that iron and ſteel may be reſpectively welded together by application in this ſtate; an effect which it would be very difficult to account for, in this moſt infuſible of metals, if it were not for ſuch an admixture. But caſt ſteel, ſteel over-cemented, and crude iron, appear to be in the ſtate of all other metals, platina excepted. They cannot be welded, becauſe welding implies a partial fuſion; or an effect ſimilar to the gluing or uniting of ſolids by the application of a fluid, which afterwards becomes conſiſtent. And if it be true that platina poſſeſſes this valuable property, it ſeems reaſonable to infer that it muſt alſo conſiſt of two metallic ſubſtances of different degrees of fuſibility.

Probable cauſe of the property of welding.

Platina.

Crude iron and ſteel.

Crude iron, and ſteel of an uniform texture, conſiſt therefore of a fuſible combination of iron with the combuſtible ſubſtance of the coal, or ſomething which is imparted from it; the crude iron differing from the ſteel ſimply in being over-cemented, and leſs pure, on account of the admixture of metallic calx, which can ſcarcely, perhaps, be avoided in the large

3 proceſs.

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procefs. It appears therefore that crude iron muft pafs through the ftate of fteel before it can become forged iron; and confequently that the fabrication of fteel from this laft is a circuitous procefs, which can only be repaid by the abfence of thofe unreduced parts which may exift in the crude iron. At fome forges, however, where the ore, the flux, the fuel, and the management, are adapted to each other, the produce affords fteel, when duly refined. At other manufactories, the crude iron is either refined, or converted into fteel, by running it into thin plates, which are ftratified with charcoal, and burned in a clofe furnace. In this way, the metal is refined by degrees, without undergoing fufion; and if the heat be raifed to that of cementation, the iron will not only be reduced, but converted into fteel. In the forges of Carinthia the grey crude iron is alfo converted either into foft iron, or fteel, according to the management of a fomewhat fimilar procefs. The iron is fufed in a large melting pot; and a fmall quantity of water being thrown upon the furface of the metal, caufes a thin plate to congeal, which is taken off; and, by continuing the operation, the greateft part of the fufed iron becomes converted into plates. To produce fteel, thefe plates are again fufed, and kept a long time in an elevated heat; at the fame time that the metal is defended from the contact of the air by a fufficient quantity of the vitreous flag. To produce foft iron, the plates are expofed to a continued roafting, while the air is conftantly renewed by means of two pair of bellows. The extenfive furface of the plates renders

Proceffes for refining crude iron, and making fteel in a direct way.

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it unneceſſary to uſe that agitation, or ſtirring, which is required when fuſed crude iron is refined. In theſe proceſſes it is evident that the ſame matter in the crude iron, which it obtained in the ſmelting furnace, is employed, and ſupplies the place of the charcoal of cementation in forming the ſteel; and, on the other hand, that this ſubſtance, which prevented the crude iron from being ſoft, tough, and infuſible, is burned away, together with a portion of the iron itſelf, while the remainder is left in a much purer ſtate.

The exiſtence of plumbago in crude iron and ſteel; aſcertained in the dry way.

Theſe are the facts obſerved at the furnaces. But the obſervations and inquiries of the chemiſt muſt be carried farther, in order to determine what it is that iron gains or loſes at the time of its converſion into its various ſtates. It is found that crude iron approaches towards the ſoft ſtate, not only by heating with expoſure to air, which burns the combuſtible addition, but likewiſe by fuſion, without the free acceſs of air. In this caſe, when the fuſion has been complete, and the cooling gradual, it is found that a black ſubſtance is thrown up to its ſurface, which is more abundant the greyer or blacker the iron; and the ſame black ſubſtance is obſerved to coat the ladles of forged iron, which are uſed to take out the metal, and pour it into moulds for caſting ſhot, and other articles. It appears therefore that the heated iron, like other heated fluids, is capable of holding a larger quantity of matter in ſolution than when cold; and that a portion of this black ſubſtance ſeparates during the cooling, whether by the gradual effect of ſurrounding bodies or by the contact of the ladle, in the ſame

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manner as various falts are feparated, in part, from water by a diminution of temperature. From chemical analyfis, as well as from its obvious characters, this black fubftance is found to be plumbago, or the material ufed to make pencils, and commonly known by the name of black lead.

Plumbago extricated from iron in the humid way.

The prefence of this black matter is likewife exhibited by diffolving fteel, or crude iron, in acids, in which plumbago is infoluble, and therefore remains behind in the form of a powder. Hence likewife is deduced the caufe of the black fpot which remains upon fteel, or crude iron, after its furface has been corroded by acids; for this fpot confifts of the plumbago which remains after the iron has difappeared by folution.

Quantities of plumbago, and of inflammable air, afforded by various kinds of iron.

Solution in the vitriolic or marine acids, not only exhibits the plumbago contained in iron, but likewife poffeffes the advantage of fhewing the ftate of its reduction by the quantity of inflammable air which is difengaged: for whether this aërial fluid be fupplied by the phlogifton of the iron, or from the decompofed water, it is agreed on all hands that its quantity, in like circumftances, is proportional to that of the iron which is converted into calx. There are confiderable differences between the various products of the fmelting furnace in thefe refpects; but it is found that the white crude iron affords the leaft quantity of inflammable air in proportion to its bulk, and leaves a moderate portion of plumbago; the grey crude iron affords more inflammable air, and more plumbago, than the white; and the fofteft bar iron affords moft inflammable air of any, and little or no plum-

 bago.

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bago. The quantities of inflammable air *, at a medium, by ounce meafures, were 62, afforded by 100 grains of the white crude iron; 71 by the grey crude iron; and 77 by the malleable iron.

Degrees of reduction and cementation in iron.

Hence it may be inferred that, in the white crude iron, the proceffes of reduction and cementation are both carried to a lefs extent than in the grey crude iron, which is produced by means of a ftronger heat, excited with a larger quantity of fuel: and that the reduction of grey crude iron is ftill lefs perfect than that of the foft bar iron; though this laft, by the refining in an open veffel, is fo far from being more cemented, that it fcarcely contains any plumbago at all.

Inaccuracies.

It muft be admitted, however, that the folution in acids ferves only to fupport thefe general conclufions, in conjunction with the facts obferved in the dry proceffes; but cannot accurately fhew either the quantities of inflammable air or plumbago afforded by the feveral kinds of iron. For the plumbago, as it becomes difengaged, floats on the top of the vitriolic acid; where it gradually difappears, though infoluble in that acid. It muft therefore be taken up by the inflammable air; and it is found that the volume of this air is diminifhed by the abforption. Hence there is a double fource of inaccuracy from the lofs of plumbago, and the contraction of the inflammable air.

Plumbago.

As plumbago appears to be a compound of iron and combuftible matter, and as the properties and

* Acad. Par. 1786, pages 166, 167. The numbers in the text are given as a rough meafure; for, in fact, there can be no medium.

effects

effects of iron, in its various ſtates, cannot be well underſtood without a reference to thoſe of this ſubſtance, it will be expedient to give an account of it in this place, inſtead of referring it to the next ſection. IRON.

Characters of plumbago.

Plumbago, or black lead, is a well-known ſubſtance, of a black colour, and ſhining appearance, when cut. Its texture is rather ſcaly; but its fracture exhibits a granular and dull appearance. None of the ſpecimens have any conſiderable hardneſs. This mineral is found in England, Germany, France, Spain, and Africa; but the ſort beſt adapted for making pencils comes chiefly from Borrowdale in Cumberland. For this purpoſe, it is carefully ſawed into narrow ſlips, or pieces, not more than one-tenth of an inch thick; which are glued between two half cylinders of cedar wood. An inferior kind of pencils is made by the Jews, by mixing the powder or ſaw-duſt with gum arabic, or fuſing it with reſin or ſulphur; and preſſing or pouring it into the cavities of reeds. The powder of plumbago, with three times its weight of clay, and ſome hair, makes an excellent coating for retorts; and the black lead or Heſſian crucibles are compoſed of the ſame materials.

Habitudes.

Plumbago is not ſubject to alteration by expoſure to the action of air or water; and it is inſoluble in acids. In cloſed veſſels it is either entirely, or nearly, unalterable by the ſtrong heat of a furnace; but by continued ignition, and occaſional ſtirring in a ſhallow veſſel, under a muffle, it is gradually diſſipated, or burned, leaving a reſidue of calx of iron, of about one-tenth of the original weight. It detonates with nitre in a red heat; ten parts of this ſalt are required

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Experiments tending to difcover the component parts of plumbago.

quired to one of plumbago before the whole will be decompofed, and exhibit no refidue of plumbago when the alkali is diffolved in water. The aërial product of this detonation is found to confift of a mixture of one-third fixed air; and the reft air which maintains combuftion: the alkali contains fixed air; and fome of the nitre is driven up by the heat. In order to fhew that the fixed air came from the plumbago, and not from the nitre, the firft analyfer * of this fubftance detonated tin, antimony, and fulphur, refpectively, with nitre, and obtained no fixed air: and, ftill more to place the inference beyond a doubt, he expofed plumbago to diftillation, with twice its weight of dry acid of arfenic: the acid was reduced to the ftate of white calx and fublimed; and pure fixed air came over. Similar refults were had with the calces of mercury and lead; the metals were revived, and fixed air was expelled. When pulverized plumbago was diftilled with cauftic fixed alkali by a ftrong heat, the volatile product was inflammable air; and the remaining alkali contained fixed air.

Phlogiftic theory.

From thefe, and other facts, he concluded, that plumbago is a compound of phlogifton and fixed air, with a little iron, which he fuppofed to be accidental. The exiftence of the phlogifton was judged to be proved by its detonation with nitre, as well as by the revival of the acid of arfenic and the metallic calces, and the extrication of inflammable air by alkali: he inferred the quantity of phlogifton in this fubftance to be twice as much as in charcoal; becaufe it re-

* Scheele. See his Effays, Eng. Tranf. Effay XIII.

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quires twice the quantity of nitre for its detonation. The presence of fixed air was deduced from the aërial products in all the distillations but the last; and from the mild state of the alkalis, in those trials wherein they were used.

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Antiphlogistic theory of plumbago.

The antiphlogistic philosophers * consider plumbago as a compound of iron, and the acidifiable base of fixed air, which they call carbone, because it exists most abundantly in charcoal. The difficulty of burning or decomposing it, is considered as a consequence of the combination of its parts, which are less disposed to unite with vital air, than either would be if alone. The same difficulty accounts for the large proportion of nitre required to deflagrate with it completely; a quantity required, not because there is much combustible matter to be burned, but because a long continued and elevated heat is necessary; by which means much of the nitre is decomposed, and its vital air flies off, without having been employed in the combustion, as appears by the two thirds of the elastic product, which will support the flame of a candle. The other facts are easily adapted to this theory. By detonation with nitre it affords fixed air, because the combustible base is acidified by the vital air of the nitre. The arsenical acid, and metallic calces, are reduced by the abstraction of the vital air they contained; which vital air, combining with the acidifiable base contained in the plumbago, converts it into the fixed air, or acid, which flies off: And, lastly, in the distillation of plumbago with humid alkali, a de-

* Acad. Par, 1785, pag. 132, et seq.

compo-

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composition of the water takes place: its inflammable air flying off; and its vital air, combining with the acidifiable base, as before, forms fixed air, which unites with the alkali, and renders it mild.

Resemblance between plumbago and pyrites.

The chief difference in the matter of fact between these theorists appears to consist in the iron; which the latter consider as a necessary part of the combination; by means of which they account for its difficult combustibility. Since plumbago does really contain iron, it may be considered as a compound of a similar nature to the martial pyrites. Thus in the pyrites iron is united to sulphur; which the phlogistian philosophers assert to be a compound of vitriolic acid (or its base) and phlogiston, while their opponents take the sulphur to be a simple substance, capable of acidification by the addition of vital air: and so likewise plumbago is a compound of iron, united to another substance; which the phlogistians assert to be fixed air, combined with phlogiston; at the same time that the other party, rejecting the inflammable principle, affirm that it is the simple acidifiable base, which will form fixed air when vital air is added to it. We see therefore that it is the explanation, and not the facts, which forms the object of contention.

Page 417. 149.

Recapitulation of the facts relating to the states of iron.

Since crude iron, then, contains the base of fixed air in combination, of which it may be deprived by heat with access of vital air, which converts it into the acid state; and since it again recovers that base by cementation with charcoal, there can be no doubt but the plumbago is afforded by the fuel, it being highly probable that iron is necessary to its separate existence. It appears also that the reduction of the

the metallic calx takes place firſt at a lower temperature; and that the combination of the baſe of fixed air follows at a greater heat. Whence, in the refining of iron, the plumbago is firſt burned, and the iron remains reduced; and, in the cementation of bar iron, the metal is converted into ſteel, with bliſters on its ſurface; which moſt probably ariſe from fixed air formed by the vital air of ſome portions of unreduced calx, uniting with the acidifiable baſe from the charcoal. And, laſtly, as iron holds this acidifiable baſe, or phlogiſticated acid, in ſolution, ſo likewiſe it may not be ſeparable from this metallic ſolvent, without carrying a portion with it; in the ſame manner as ſalts, which cryſtallize in water, always take up part of the ſolvent in the formation of their cryſtals.

Refining.

Cementation.

It would require many volumes to enumerate the leading uſes of iron. This moſt valuable of metals is applied to ſo many, and ſuch important uſes, that we cannot look round us without ſeeing its effects. When we contemplate the innumerable effects of human induſtry, and aſk ourſelves the ſimple queſtion, could this have been done without iron? there is not a ſingle inſtance which will not immediately ſhew its value. It is indeed difficult to form an idea, how civilized ſociety could exiſt without it.

Uſes of iron.

CHAP. VIII.

CONCERNING TIN.

TIN.

Characters of tin.

TIN is a metal of a yellowiſh-white colour, conſiderably harder than lead, ſcarcely at all ſonorous, very malleable, though not very tenacious. Wires cannot be made of it; but, under the hammer, it is extended into leaves, called tin foil, which are about one-thouſandth of an inch thick; and might eaſily be beaten to leſs than half that thickneſs, if the purpoſes of trade required it. The proceſs for making tin foil conſiſts ſimply in hammering out a number of plates of this metal, laid together upon a ſmooth block, or plate of iron. The ſmalleſt ſheets are the thinneſt. Its ſpecific gravity is leſs than that of any other malleable metal. Long before ignition, it melts at about the 410th degree of Fahrenheit's thermometer; and, by a continuance of the heat, it is ſlowly converted into a white powder by calcination. Like lead, it is brittle when heated almoſt to fuſion; and exhibits a grained or fibrous texture, if broken by the blow of a hammer; it may alſo be granulated by agitation at the time of its tranſition from the fluid to the ſolid ſtate. The calx of tin reſiſts fuſion more ſtrongly than that of any other metal; from which property, it is uſeful to form an opake white enamel, when mixed with pure glaſs in fuſion. The brightneſs of its ſurface, when ſcraped, ſoon goes off by

expoſure

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exposure to the air; but it is not subject to rust, or corrosion, by exposure to the weather.

Solution of tin in vitriolic acid:

Concentrated vitriolic acid, assisted by heat, dissolves half its weight of tin, at the same time that vitriolic acid air escapes in great plenty. By the addition of water a calx of tin is precipitated. Vitriolic acid, slightly diluted, likewise acts upon this metal; but if much water be present, the solution does not take place. In the vitriolic solution of tin there is an actual formation, or extrication of sulphur, which renders the fluid of a brown colour whilst it continues heated, but subsides by cooling. The tin is likewise precipitated in the form of a white calx by a continuance of the heat, or by long standing without heat. This solution affords needle-formed crystals by cooling.

— in nitrous acid.

Nitrous acid and tin combine together very rapidly, without the assistance of heat. Most of the metal falls down in the form of a white calx, extremely difficult of reduction; and the small portion of tin which remains suspended, does not afford crystals, but falls down, for the most part, upon the application of heat, to inspissate the fluid. The strong action of the nitrous acid upon tin produces a singular phenomenon, which is happily accounted for by the modern discoveries in chemistry. Mr. De Morveau * has observed that, in a solution of tin by the nitrous acid, no elastic fluid was disengaged; but that volatile alkali was formed. This alkali must have been produced by the phlogisticated air of that part of the nitrous acid

Singular effect.

* Kirwan on Phlogiston, 2d edition, p. 234.

TIN.

Volatile alkali produced from nitrous acid, &c.

which was employed in affording pure air to calcine the tin. The phlogifticated air muft therefore have combined with inflammable air: but whether this inflammable air was afforded by a decompofition of the water of the menftruum, or whether it came from the phlogifton of the tin, is a queftion that muft remain undetermined, until decifive experiments have been made for the eftablifhment of one or the other of the two theories, which at prefent divide the chemical world.

Solution of tin in marine acid:

The marine acid diffolves tin very readily, at the fame time that it becomes of a darker colour, and ceafes to emit fumes. A flight effervefcence takes place with the difengagement of a fetid inflammable gas. Marine acid fufpends half its weight of tin, and does not let it fall by repofe. It affords permanent cryftals by evaporation. If the tin contain arfenic, it remains undiffolved at the bottom of the fluid.

— in dephlogifticated marine acid:

Dephlogifticated marine acid diffolves tin very readily, and without fenfible effervefcence. The folution itfelf does not appear to differ from the foregoing.

—in aqua regia.

Aqua regia, confifting of two parts nitrous and one marine acid, combines with tin with effervefcence, and the developement of much heat. In order to obtain a permanent folution of tin in this acid, it is neceffary to add the metal by fmall portions at a time; fo that the one portion may be entirely diffolved before the next piece is added. Aqua regia, in this manner, diffolves half its weight of tin. The folution is of a reddifh brown, and in many inftances affumes the form of a concrete gelatinous fubftance. The addition of water fometimes produces the con-

crete

crete form in this solution, which is then of an opal colour, on account of the calx of tin diffused through its substance. The uncertainty attending these experiments, with the solution of tin in aqua regia, seems to depend upon the want of a sufficient degree of accuracy in ascertaining the specific gravities of the two acids which are mixed; the quantities of each, and of the tin, together with that of the water added. It is probable that the spontaneous assumption of the concrete state depends upon water imbibed from the atmosphere. The solution of tin in aqua regia is used by dyers to heighten the colours of cochineal, gum lac, and some other red tinctures, from crimson to a bright scarlet, in the dying of woollens.

TIN. Solution of tin in aqua regia.

M. Hermstædt has succeeded in the actual acidification of this metal, by treating it with the marine and nitrous acids. He dissolves pure tin in pure marine acid, and boils this solution with nitrous acid distilled from manganese) until the red vapours cease to appear. The fluid, which is then limpid, is exposed to distillation until the whole of the marine and nitrous acids have been dissipated. The white remaining mass is soluble in three parts of water, and is the acid of tin. A red heat converts this matter into a yellow transparent substance, neither acid nor soluble in water; but it regains both properties by a few weeks exposure to the air *.

Acid of tin.

The acetous acid scarcely acts upon tin. The operation of other acids upon this metal has been little inquired into.

* Journal de Phys. xxxv. 391. Nov. 1789.

TIN.

The fuming liquor of Libavius.

When equal parts of an amalgam of tin and mercury, and of corrofive fublimate, are triturated together, and the mixture expofed to diftillation in a retort, by a very gentle heat; a colourlefs fluid firft comes over, which is followed by a thick white fume, which becomes condenfed into a tranfparent liquor, called the fuming liquor of Libavius, on account of the copious fumes it emits when the veffel that contains it is opened. On account of the confiderable volatility of this liquid, it rifes, partly in the form of flowers, to the top of the bottle in which it is put; fo that, in the courfe of feveral months, it becomes entirely clofed. The compofition and effects of this liquid were but imperfectly known until lately, when Mr.

Adet's examination of the fuming liquor of Libavius.

Adet made feveral ingenious experiments upon it. By expofing this liquid under receivers containing dry air, over mercury, he found that the volatile fluid arofe, and lined the veffel with cryftals, when water was prefent; though very few cryftals were formed when the air was as dry as it could be made. He obferved likewife, that when water was added to the fuming liquor of Libavius, it became folid, and ceafed to emit fumes. A precife quantity of water is required to produce this effect in the moft perfect manner. If the quantity of water be too fmall, the liquor retains more or lefs of its difpofition for the fluid ftate; and if it be too confiderable, the fluidity of the water prevails. By feveral trials he found that the due proportion of water to be added to the fuming liquor of Libavius was as 7 to 22. A kind of ebullition, or efcape of bubbles, was produced during the combination; which, on examination, was found to arife from the

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the efcape of the air previoufly contained in the fluid water. He found likewife that this concrete fubftance, when rendered fluid by an increafe of temperature, was capable of diffolving more tin, without the difengagement of inflammable air. After the concrete fubftance was faturated with tin, it could no longer be fublimed, but might be made to undergo a red heat; during which time there was an efcape of vapours, confifting of tin combined with the marine acid; and, after a ftrong heat, the refidue was a white calx of tin. It appeared therefore that the liquor of Libavius, rendered concrete by water, and faturated with tin, refembles, in its properties, the common folution of tin in the marine acid.

Adet's examination of the fuming liquor of Libavius.

From thefe circumftances, Mr. Adet concludes that the tin, by ftronger affinity, combines with the aërated or dephlogifticated marine acid of the corrofive fublimate with which it is heated; that this combination contains no water; and that, as it abounds with a fubftance of fuch extreme volatility as that aërated acid, its freezing point is very low, infomuch that it is habitually fluid; that the addition of water, in a due proportion, alters the freezing point, and renders it concrete at a common temperature; and, laftly, that the ftate of the marine acid in this fubftance is that which is called aërated, or dephlogifticated; which is proved as well from the experiments which afcertain that ftate in corrofive fublimate, as from fimilar experiments with the fuming liquor, which, as has been obferved, is capable of diffolving more tin without difengaging inflammable air. The fuming liquor of Libavius has therefore Page 262.

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the fame relation to the common folution of tin as corrofive fublimate has to calomel *.

The refidue, after the diftillation by which the fuming liquor of Libavius is produced, confifts of tin combined with the marine acid, calomel, and running mercury, which fublime into the roof and neck of the retort; and at the bottom is found an amalgam of mercury and tin, covered with a faline combination of marine acid with tin, and fuch other metals as the tin may have been adulterated with. Much information may be derived from the foregoing experiments of Mr. Adet refpecting the phenomena produced when tin is diffolved in aqua regia.

Habitudes of tin, with earths and neutral falts:

Earthy fubftances do not appear to affect this metal in the dry way. It detonates very rapidly with nitre, and becomes converted into a calx, which partly combines with the alkali. All the vitriolic falts are decompofed by tin. The tin becomes calcined, and the vitriolic acid converted into fulphur, either by the phlogifton of the metal, according to the ancient theory; or by the fubtraction of its vital air, according to the modern theory. This fulphur appears to combine with the alkali, or earth of the falt, with which it forms an hepar that diffolves part of the calx.

— with fal ammoniac.

Sal ammoniac is very readily decompofed by tin. Alkaline and inflammable air are difengaged; and a concrete marine falt remains behind, which, in fome meafure, refembles the fuming liquor of Libavius. The volatile alkali, or alkaline air, which efcapes, is

* Annales de Chimie, i. 1, &c.

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disengaged by virtue of the superior affinity of the calx of tin with the marine acid, at the temperature of the experiment. The inflammable air, which likewise flies off, is a consequence of the calcination of the tin; and will be derived either from the phlogiston of the tin, or the decomposition of the water, according to the theory which may be applied in the explanation. Notwithstanding the facility with which this metal decomposes sal ammoniac, there is an inconvenience resulting from its use, which depends on the great fusibility of this metal; in consequence of which, it cannot be intimately mixed with the sal ammoniac, but remains at the bottom of the vessel in the fluid state; while part of the sal ammoniac eludes its action, and is sublimed entire.

Spontaneous decomposition and inflammation of metallic salts.

If the crystals of the saline combination of copper with the nitrous acid be grossly powdered, moistened, and rolled up in tin-foil, the salt deliquesces, nitrous fumes are emitted, the mass becomes hot, and suddenly takes fire. In this experiment * the rapid transition of the nitrous acid to the tin is supposed to produce or develope heat enough to set fire to the nitrous salts; but by what particular changes of capacity, has not been shewn.

Combination of tin with sulphur.

If sulphur, in powder, be added to about five times its weight of melted tin, the two substances combine, and form a black compound, which takes fire, and is much less easily fused than the tin itself. The mass is brittle, and of a needled texture.

Aurum musivum.

The combination of tin and sulphur, called aurum

* Of Dr. Higgins. Philos. Trans. lxiii. p. 137.

TIN.

musivum, is thus made: Melt twelve ounces of tin, and add to it three ounces of mercury; triturate this amalgam with seven ounces of sulphur, and three of sal ammoniac. Put the powder into a matrass, bedded rather deep in sand, and keep it for several hours in a gentle heat; which is afterwards to be raised, and continued for several hours longer. If the heat has been moderate, and not continued too long, the golden-coloured scaly porous mass, called aurum musivum, will be found at the bottom of the vessel; but, if it has been too strong, the aurum musivum fuses to a black mass, of a striated texture. This process is thus explained: As the heat increases, the tin, by stronger affinity, seizes, and combines with, the marine acid of the sal ammoniac; while the alkali of that salt, combining with a portion of the sulphur, flies off in the form of an hepar. The combination of tin and marine acid sublimes, and is found adhering to the sides of the matrass. The mercury, which served to divide the tin, combines with part of the sulphur, and forms cinnabar, which also sublimes; and the remaining sulphur, with the remaining tin, forms the aurum musivum, which occupies the lower part of the vessel. It must be admitted, however, that this explanation does not indicate the reasons why such an indirect and complicated process should be required to form a simple combination of tin and sulphur.

Aurum musivum.

Combination of tin with phosphorus.

When tin is heated with phosphoric acid and charcoal, the metal appears to be very little changed. A combination, however, seems to take place; for the phosphorus burns on the surface of the metal when heated by the blow-pipe.

Tin

TIN.

Metallic mixtures.

Tin unites with bismuth by fusion; and becomes harder and more brittle, in proportion to the quantity of semi-metal added. With nickel it forms a white brilliant mass. It cannot easily be united in the direct way with arsenic, on account of the volatility of this semi-metal; but, by heating it with the combination of the arsenical acid and vegetable alkali, the salt is partly decomposed; and the tin, combining with the acid, becomes converted into a brilliant brittle compound, of a plated texture. It is thought that all tin contains arsenic; and that the crackling noise which is heard upon bending pieces of tin is produced by this impurity. Cobalt unites with tin by fusion; and forms a grained mixture, of a colour slightly inclining to violet. Zinc unites very well with tin, increasing its hardness, and diminishing its ductility, in proportion as the quantity of zinc is greater. This is one of the principal additions used in making pewter, which consists, for the most part, of tin. The best pewter does not contain above one-twentieth part of admixture, which consists of zinc, copper, bismuth, or such other metallic substances as experience has shewn to be most conducive to the improvement of its hardness and colour. The inferior sorts of pewter, more especially those used abroad, contain much lead, have a blueish colour, and are soft. The tin usually met with in commerce in this country has no admixture to impair its purity, except such as may accidentally elude the workmen at the mines. But the tin met with in foreign countries is so much debased by the dealers in that article, especially the Dutch, that pewter and tin are considered

Pewter.

Mistake of foreigners respecting English tin.

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abroad as the fame fubftance. Regulus of antimony forms a very brittle, hard, mixture with tin; the fpecific gravity of which is lefs than would have been deduced by computation from the fpecific gravities and quantities of each, feparately taken. Wolfram, fufed with twice its weight of tin, affords a brown fpungy calx, which is fomewhat ductile.

Native tin.

Tin is fcarcely ever found native. Native tin may be analyfed, in the moift way, by the application of nitrous acid, which calcines the tin, and diffolves the other metals it may contain. One hundred and forty grains of the wafhed and dried calx are equivalent to one hundred grains of metallic tin. The metallic admixtures may be feparated from the nitrous acid by methods adapted to their refpective properties; which may be eafily gathered from what has already been obferved in the humid analyfis of the metals before treated of.

Calciform ores of tin.

The calciform ores of tin are—tin fpar, which is generally of a whitifh or grey colour, fometimes greenifh or yellowifh, femi-tranfparent, and cryftallized in a pyramidical form, or irregularly—opake brown or black tin ore, cryftallized, and embodied in quartz, fluor, or mica, or mixed with white and yellow pyrites; thefe ores contain a mixture of iron—the reddifh yellow, or garnet ore, which contains more of iron than of tin—and the tin ftone, vulgarly called leadftones, which contain ftill lefs tin.

Tin ores containing arfenic;

It was formerly fuppofed that tin was frequently mineralized by arfenic; but it is now admitted that the arfenic, which may be contained in tin, is afforded

and fulphur.

by the matrix. The fcarcity of fulphureous tin ores

TIN.

was likewise considered, till lately, as a very singular fact, on account of the facility with which that substance unites to tin: such combinations, however, have since been found. The native aurum musivum, from Siberia, is of this kind: and a very considerable vein of tin in combination with sulphur, and an admixture of copper and iron, has been found in Cornwall*. The analysis of tin ores in the humid way is an object of some difficulty; because they are not acted upon effectually either by the vitriolic, nitrous, or marine acids, or by aqua regia. The method of Bergman is as follows: The ore must be reduced to a very subtile powder by levigation and elutriation. This last process consists in agitating any powder in water, which is heavy enough to sink in that fluid. The particles will be resisted in their descent, according to the surfaces they oppose against the fluid. It is scarcely necessary to observe, that a larger body presents a less surface to be resisted, than the same body would oppose if it were divided into parts. For this reason, when a powder, consisting of particles of the same density, but different magnitudes, is agitated in a lighter fluid, the largest pieces come first to the bottom: and hence the method of elutriation enables us to assort the various particles of a powder according to their magnitudes, by first agitating the fluid, and successively decanting it into different vessels. Thus, for example, if the water be decanted five seconds after the agitation, it will leave a powder behind it; if it

Process of elutriation described and explained.

* See Magellan's Cronstedt, p. 637. The contents of one specimen were 30 parts sulphur, 41 tin, 43 copper, 2 iron, and stony matrix.

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TIN.

be again decanted, at the end of five feconds more, the fecond veffel will contain a much finer powder than the foregoing; and, by a third decantation, a ftill more fubtile powder will be obtained. This is the method applied in the preparation of the white calx of tin, called putty, and ufed for polifhing fine metallic fpeculums, and the object lenfes of telefcopes; and in this way the tin ore to be analyfed, may be reduced to a very fubtile powder, by levigating and again wafhing the coarfe refidue which fubfides in the firft veffel. It may be obferved, that the fucceffive decantations are unneceffary where the very fineft powder only is wanting; becaufe this may be as well obtained by fuffering the water to ftand a fufficient time before it is decanted off at firft. To the very fubtile powder of tin ore, thus afforded, a quantity of concentrated vitriolic acid muft be added, and kept in a ftrong digefting heat for feveral hours. A fmall portion of concentrated marine acid muft be poured into this when cold. A ftrong effervefcence takes place with confiderable heat and the efcape of marine acid air, which has been deprived of its water by the vitriolic acid. After the expiration of an hour or two, fome water muft be added, and the clear liquor decanted. The fame operation muft be repeated with the refiduum, until the acids can diffolve no more: and nothing will then remain but the ftony matrix. The folution, when precipitated by means of mild alkali, will afford 100 grains of metallic tin for each 132 grains of precipitate, when wafhed and dried. If the precipitate do not confift of pure tin, but contain copper or iron, it muft be calcined for an hour

Putty.

Analyfis of tin ores, in the humid way:

in

in a red heat; then digefted in nitrous acid, which will take up the copper; and afterwards in marine acid, which will diffolve the iron.

— in the dry way.

In the dry way, after pulverization, and feparation of the ftony matter by wafhing, the tin ores may be haftily fufed with twice their weight of a mixture of pitch and calcined borax, in a crucible lined with charcoal, and covered; or the ore may be mixed with twice its weight of tartar, one part of black flux, and half a part of refin. This mixture being then divided into three parts, each part muft be fucceffively projected into a crucible ignited to whitenefs, which muft be immediately covered as foon as the portion thrown in ceafes to flame.

Reduction of tin in the large way.

The operation of reducing tin ores in the large way, is conducted upon fimilar principles. When impure, they are cleanfed from foreign admixtures, by forting, pounding, and wafhing. A flight previous roafting renders the ftony parts more friable; and, when arfenic is contained in the matrix, it is driven off by a ftrong heat, continued for a fhort time; the ore being frequently ftirred, to prevent its running together by fufion. In the fmelting of the ore, care is taken to add a larger quantity of fuel than is ufual in the reviving of other metals; and to avoid a greater heat than is neceffary to reduce the ore, in order that the lofs by calcination may be prevented as much as poffible.

Countries which afford tin.

Tin is a metal which, as far as our prefent information extends, is not very much diffufed. It is found in Bohemia and Saxony, and on the ifland of Malacca in the Eaft-Indies. But the largeft quantities, TIN. ties, at leaſt for the European conſumption, are found in England; particularly in the county of Cornwall. This iſland has been famous for its tin mines from the remoteſt periods of hiſtory; and would not, probably, have been frequented by the ancient Phœnician navigators, if they had not been attracted hither by the great plenty of tin with which it abounds. Several etymologiſts have endeavoured to ſhew that the name of Britain is derived from a word common to the Syrian and Chaldean languages, denoting tin; but on this no great ſtreſs can be laid.

Uſes. The uſes of tin are very numerous, and ſo well known, that they ſcarcely need be pointed out. Several of them have already been mentioned. The tinning of iron and copper, the ſilvering of looking-glaſſes, and the fabrication of a great variety of veſſels and utenſils for domeſtic and other uſes, are among the advantages derived from this metal.

CHAP.

CHAP. IX.

CONCERNING BISMUTH.

BISMUTH. Characters of bismuth.

BISMUTH is a semi-metal, of a yellowish or reddish-white colour, little subject to change in the air. It is somewhat harder than lead, and is scarcely, if at all, malleable; being easily broken, and even reduced to powder by the hammer. The internal face, or place of fracture, exhibits large shining plates, disposed in a variety of positions: thin pieces are considerably sonorous. At a temperature not exceeding the 460th degree of Fahrenheit it melts; and its surface becomes covered with a greenish, grey, or brown calx. A stronger heat ignites it, and causes it to burn with a small blue flame; at the same time that a yellowish calx, known by the name of flowers of bismuth, is driven up. This calx appears to rise in consequence of the combustion; for it is very fixed, and runs into a greenish glass when exposed to heat alone. Bismuth, urged by a strong heat, in a closed vessel, sublimes entire. This semi-metal crystallizes very distinctly, when gradually cooled.

Action of vitriolic acid.

The vitriolic acid has a slight action upon bismuth, when it is concentrated, and boiling. Vitriolic acid air is exhaled, and part of the bismuth is converted into a white calx. A small portion combines with the vitriolic acid, and affords a deliquescent salt, in the form of small needles.

The

BISMUTH.

Solution in nitrous acid.

The nitrous acid attacks bifmuth with the greateft rapidity and violence; at the fame time that much heat is extricated, and a large quantity of nitrous air efcapes. The folution, when faturated, affords cryftals as it cools: the falt detonates weakly, and leaves a yellow calx behind, which efflorefces in the air. Upon diffolving this falt in water, it renders that fluid of a milky white, and lets fall a calx of the fame colour.

White calx, or magiftery of bifmuth.

The nitrous folution of bifmuth exhibits the fame property when diluted with water; moft of the metal falling down in the form of a white calx, called magiftery of bifmuth. This precipitation of the nitrous folution, by the addition of water, is the criterion by which bifmuth is diftinguifhed from all other metals. The magiftery, or calx, is a very white and fubtile powder, when prepared by the addition of a large quantity of water: it is ufed as a paint for the complexion, and is thought gradually to impair the fkin. The liberal ufe of any paint for the fkin feems, indeed, likely to do this; but there is reafon to fufpect, from the refemblance between the general properties of lead and bifmuth, that the calx of this femi-metal may be attended with noxious effects fimilar to thofe which the calces of lead are known to produce.

Solution in marine acid.

The marine acid does not readily act upon bifmuth. It is neceffary that the acid fhould be concentrated, and kept a long time in digeftion upon it; or that it fhould be diftilled from the femi-metal. The refidue, when wafhed with water, affords a faline combination, which does not eafily cryftallize, but may be fub-

BISMUTH.

sublimed in the form of a soft fusible salt, called butter of bismuth. The marine solution of bismuth likewise affords a precipitate of calx by the addition of water. Marine acid seizes the calx of bismuth, when added to its solution in nitrous acid; and forms a compound of sparing solubility, which falls to the bottom. Alkalis likewise precipitate its calx; but not of so beautiful a white colour as that afforded by the affusion of pure water.

Habitudes of bismuth with earths, salts, sulphur:

The effects of earths and alkalis upon bismuth, in the dry way, have been little attended to. Nitre calcines it, with scarcely any perceptible detonation. Sal ammoniac is not decomposed by bismuth in the metallic state, though its calx readily combines with the marine acid of that salt, and disengages the volatile alkali. Sulphur unites with bismuth by fusion, and forms a blueish grey brilliant mass, of a needle-formed texture.

— and metallic substances.

This semi-metal unites with most metallic substances; and renders them, in general, more fusible. When calcined with the imperfect metals, its glass dissolves them, and produces the same effect as lead in cupellation; in which process, it is even said to be preferable to lead.

Uses.

Bismuth is used in the compositions of pewter, in the fabrication of printers types, and in various other metallic mixtures.

Native bismuth and its ores.

It is sometimes found native, and may be analysed, in the humid way, by solution in nitrous acid, and precipitation, by the addition of water; which throws down 113 grains of calx for every 100 of metallic bismuth. It is likewise found in the calciform state;

BISMUTH.

and mineralized by fulphur, of a grey colour, refembling galena, but heavier. Thefe ores may alfo be analyfed by nitrous acid, like the foregoing.

Reduction of bifmuth ores.

Bifmuth is eafily feparable, in the dry way, from its ores, on account of its great fufibility. It is ufual, in the proceffes at large, to throw the bifmuth ore into a fire of wood; beneath which a hole is made in the ground to receive the metal, and defend it from calcination. The fame procefs may be imitated in the fmall way, in the examination of the ores of this metal; nothing more being neceffary than to expofe it to a moderate heat in a crucible, with a quantity of reducing flux; taking care, at the fame time, to perform the operation as fpeedily as poffible, that the bifmuth may be neither calcined nor volatilized.

CHAP.

CHAP. X.

CONCERNING NICKEL.

NICKEL. Characters.

NICKEL is a reddiſh white metallic ſubſtance, of great hardneſs, and of an uniform texture; very difficult to be purified, and always magnetical, whence it has been ſuppoſed to contain iron in its pureſt ſtate. It is malleable, and is ſcarcely more fuſible than pure iron. Its calces are of a green colour.

Treatment of the ores of nickel.

This metallic ſubſtance has not been applied to any uſe: and the chief attention of thoſe chemiſts who have examined it has been directed to obtain it in a ſtate of purity; which, however, has not yet been accompliſhed. It is found either native or calciform; but moſt commonly mineralized in combination with arſenic, ſulphur, cobalt, and iron, in the ore, called kupfer nickel, or falſe copper. This is of a reddiſh yellow, or coppery colour; of a texture either uniform, granular, or ſcaly; bright in its fracture, and almoſt always covered with a green efflореſcence of calx. Moſt of the ſulphur and arſenic may be driven off by long-continued roaſting, and the occaſional addition of charcoal, which prevents the arſenic from being rendered more fixed by calcination; and the green calx which remains may be fuſed by the ſtrongeſt heat of a ſmith's forge, together with two or three times its weight of black flux. The regulus thus

NICKEL.

obtained is of a reddiſh white colour, and brittle; but is very far from being pure. Repeated calcinations for many hours, and reductions, ſcarcely deprive the regulus of iron; and it is ſtill highly magnetic, when purified to ſuch a degree as to poſſeſs conſiderable malleability. Combination with ſulphur, with liver of ſulphur, detonation with nitre, and ſolution in the volatile alkali and vitriolic acid, did not deprive it of its magnetiſm.

Pureſt regulus of nickel.

When the regulus *, obtained by ſcorification and reduction, was combined with ſulphur, and reduced again after the diſſipation of the ſulphur by ſtrong heat, and the addition of charcoal, to promote the volatility of the arſenical contents; and this proceſs was three times repeated; the reduced metal was ſo infuſible, as not to run into a maſs by the ſtrongeſt heat of a ſmith's forge, continued for three quarters of an hour. Its colour was then whitiſh, mixed with a glittering kind of red; it was ſtrongly magnetical; of a ſpecific gravity of 8.66; and a globule of one line in diameter was extended by the hammer into a plate of upwards of three lines in diameter: ſo that it is, properly ſpeaking, an entire metal, and not a ſemi-metal. It afforded a blue ſolution with the volatile alkali; and in nitrous acid its ſolution was of a full green.

— Is an entire metal.

Action of vitriolic acid.

Concentrated vitriolic acid acts upon the regulus of nickel, and corrodes it. The reſidue, after diſtillation of the acid, is a greyiſh powder; part of which is in the ſaline ſtate, and affords green cryſtals by ſolution in water and evaporation.

* Bergman on Nickel, in vol. ii. of his Eſſays.

The

NICKEL.

The nitrous solution of this metal affords saline crystals. Alkalis precipitate it, and redissolve the precipitate. Nitre detonates with nickel in the dry way. Sulphur readily combines with it by fusion, as does likewise arsenic; and both adhere very pertinaciously to it, as has been already shewn.

Whether nickel be truly a peculiar metal.

Nickel has been thought to be a modification of iron. This conclusion is grounded chiefly on its magnetism, and the consideration of the very remarkable and different properties iron is known to be capable of assuming, in its several states. Others have supposed it to be an alloy of copper with various metallic admixtures. The blue colour it affords with volatile alkali, is the chief circumstance which gave rise to this opinion. But it has been very properly observed *, that many of the known metals would scarcely have endured more severe trials than this substance has undergone, without shewing indications, at least as strong, against the supposition of their being distinct bodies, as any afforded by nickel; and consequently, that so long as no one is able to produce this metal from pure iron or copper, and to explain in an intelligible way the process by which it can be generated, we must continue to regard it as a peculiar substance, possessing distinct properties. The general opinions of chemists concur in admitting the force of this reasoning.

* Bergman, ii. 264.

CHAP. XI.

CONCERNING ARSENIC.

ARSENIC. Characters.

ARSENIC in the metallic ſtate, or the regulus of arſenic, is of a bright yellowiſh white colour, ſubject to tarniſh, and grow black, by expoſure to air. It is brittle, and when broken exhibits a laminated texture. In cloſe veſſels it ſublimes entire; but burns with a ſmall flame, if reſpirable air be preſent.

White calx of arſenic:

The arſenic met with in commerce has the form of a white calx. It is brought chiefly from the cobalt works in Saxony, where zaffre is made. Cobalt ores contain much arſenic, which is driven off by long torrefaction. The ore is thrown into a furnace reſembling a baker's oven, with a flue, or horizontal chimney, nearly two hundred yards long; into which the fumes paſs, and are condenſed into a greyiſh or blackiſh powder. This is refined by a ſecond ſublimation in cloſe veſſels, with a little pot-aſh, to detain the impurities. As the heat is conſiderable, it melts the ſublimed flowers into thoſe cryſtalline maſſes which are met with in commerce.

— is in a ſaline ſtate.

The calx of arſenic is ſo far in the ſaline ſtate, as to be ſoluble in about eighty times its weight of water, at the temperature of 60°, or in fifteen times its weight of boiling water.

Regulus.

The regulus may be obtained from this calx, either by quickly fuſing it together with twice its weight of ſoft ſoap, and an equal quantity of alkali, and pouring it

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Regulus.

it out, when fused, into an hot iron cone; or by mixing it in powder with oil, and exposing it in a matrass to a sand heat. This process is too offensive to be made but in the open air, or where a current of air carries off the fumes. The decomposed oil first rises; and the regulus is afterwards sublimed, in the form of a flaky metalline substance.

Action of vitriolic acid:

Vitriolic acid does not attack the regulus of arsenic, nor its calx, when cold; but, if it be boiled upon this semi-metal, vitriolic acid air is emitted, a small quantity of sulphur sublimes, and the arsenic is reduced to the calciform state. Boiling vitriolic acid dissolves the calx of arsenic; but scarcely retains any portion of it when cold. The calx of arsenic is considerably less volatile when vitriolic acid is present, or mixed with it; but it is said that washing deprives it of the acid, and restores its properties.

— of nitrous acid:

Nitrous acid readily attacks and calcines the regulus of arsenic: it likewise dissolves the calx of this semi-metal, in considerable quantity, by the assistance of heat; and affords a crystallized deliquescent salt by evaporation, which does not detonate on red hot coals. The calx of arsenic is acidified by the action of nitrous acid distilled from it.

— of marine acid:

Boiling marine acid dissolves the regulus, and also the calx of arsenic; but affects it very little when cold. This solution affords precipitates upon the addition of alkalis.

— of aerate acid.

The dephlogisticated or aërated marine acid converts the calx of arsenic into arsenical acid.

The calx of arsenic acts, in many instances, like an acid. It decomposes nitre by distillation; the

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nitrous acid flying off, and the arſenical ſalt of Macquer remaining behind. In this proceſs, the nitrous acid appears to acidify the calx. Quadrangular nitre is affected in the ſame manner. When the white calx of arſenic is diſtilled with ſulphur, volatile vitriolic acid flies off, and a combination of a yellow colour, called orpiment, is produced; which appears to conſiſt of ſulphur, united to regulus of arſenic; that is to ſay, part of the ſulphur receives vital air from the calx; to which, according to the ancient ſyſtem, it communicates phlogiſton: and in this manner the ſulphur becomes converted into vitriolic acid; while the arſenical calx is reduced, and combines with the reſt of the ſulphur. The combination of ſulphur and arſenic which has been fuſed, is of a red colour; and known by the name of realgal, or realgar. Realgar appears to be leſs volatile than orpiment, or the yellow combination; for it remains at the bottom, while the other ſublimes: but in what reſpect they differ from each other has not been well aſcertained. It is not improbable but that the orpiment may contain the calx in a more reduced ſtate than the realgar. A ſtrong heat converts orpiment into realgar.

Diſtillation of calx of arſenic with ſulphur.

Orpiment and realgar.

Liver of ſulphur.

Saline liver of ſulphur diſſolves the calx of arſenic; but more readily attacks the regulus.

Fixed alkalis.

Watery ſolutions of fixed alkalis diſſolve the calx of arſenic; and, if they be loaded with it by means of heat, a brown tenacious maſs is produced, which acquires ſolidity, has a diſagreeable ſmell, and is called hepar of arſenic. Mineral acids precipitate part of the arſenic; but a portion of it, being acidified, adheres more tenaciouſly to the alkali. The acids occa-

ſion

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tion no precipitation from the solution of arsenic in the volatile alkali. It is not easy to explain what happens in this case, without further experiments. The solutions of calx of arsenic in alkalis differ much in their properties from the combination which is produced when the nitrous salts are decomposed by its means. This difference is accounted for from the consideration that it is the calx of arsenic in the first case, and the acid in the latter, which combines with the alkalis.

Combination of calx of arsenic, with alkalis:

A solution of the calx of arsenic acts upon metals in the humid way, most probably in consequence of its approach to the acid state.

— with metals.

The acid of arsenic being applied to the filings of the metals, in a long-necked flask, to prevent its reduction, acts upon several of the metals in a digesting heat. Gold and platina are scarcely acted upon. Silver is not attacked by digestion; but when the acid comes to be fused, the metal is dissolved, and affords a colourless glass, which is nearly transparent; soluble in water, with the loss of greatest part of the silver, which subsides in the form of a brown powder, containing a minute portion of the acid; and reducible, like the other precipitates of silver, by mere heat. Mercury is not attacked by the arsenical acid, in the heat of digestion; but when the acid and mercury are urged in a retort, by an heat which is near melting the vessel, part of the mercury combines with the acid, and forms a yellowish mass of extremely difficult fusion; very fixed, and insoluble in water. Diluted nitrous and vitriolic acids have scarcely any effect on it, but marine acid readily dissolves it. This solution, by evaporation to dryness, and distillation, affords

Action of arsenical acid—

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—on gold, platina:

—silver:

— mercury.

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Action of arsenical acid on copper:

corrosive sublimate, and the residue is arsenical acid: whence it follows, that the mercury in the arsenical combination must have been perfectly calcined. Copper is dissolved by the arsenical acid in digestion, and affords a green solution. One part of copper filings, mixed with two of dry arsenical acid, affords a blue mass by fusion, at an elevated degree of heat, which is soluble in water; and then proves to be the same combination as was produced by digestion. The watery solution lets fall a light blue powdery matter, consisting of a combination of copper with arsenical acid.

— on iron:

Iron likewise is attacked by this acid during digestion; and the whole solution at last grows gelatinous, if the digestion be performed in an open vessel. If the digestion be performed in a long-necked or close vessel, it does not become gelatinous; but will afterwards become so, if exposed to the air. In the dry way, when one part of iron filings is distilled with four of acid of arsenic, the mass makes a great effervescence towards the end; and, when it becomes dry, it takes fire upon increasing the heat; arsenic and regulus of arsenic being sublimed, and a black friable residuum being left at the bottom, which contains but little acid of arsenic. In this process it appears that the iron, which is a metal very much disposed to combustion or calcination, suddenly deprives the arsenical acid of its vital air, and reduces it to the state of calx and regulus; at the same time that, according to the ancient hypothesis, phlogiston passes from the metal to the acid.

— on lead:

Little effect is produced upon lead by digestion with the arsenical acid; but the combination takes

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Action of arsenical acid on tin:

—on zinc.

·es place by fusion in the dry way, which affords ·emi-opake glass. When this is boiled in distilled ·ter, the lead falls down in the form of a white ·vder, containing arsenical acid, but which does not ·rd arsenic by heat, unless charcoal be added. Tin, ·ested with arsenical acid, grows black at first; ·erwards becomes covered with a white powder; ·, at last, the whole mass becomes gelatinous. In · dry way, one part of tin filings, with two of · acid, heated in a retort, took fire when ignited: · the calx of regulus of arsenic immediately sub-·ed, leaving a limpid solution of tin; which, when ·led, was of a milky colour. This, when dissolved ·distilled water, deposited a white calx, which con-·ed very little acid of arsenic.

·inc is the only metallic substance which effer-·ces when digested with the arsenical acid. The · grows black; and the transparency of the acid ·destroyed by a quantity of black powder; which, ·examination by burning on a red hot iron, proves ·e regulus of arsenic. This precipitated regulus ·n defends the zinc from farther solution. The ·which escapes during the effervescence is inflam-·ble, holding regulus of arsenic in solution, which ·eposits on burning. Either of the chemical the-·s will serve to explain these effects: for the zinc ·calcined by receiving the vital air of the acid; ·le it is supposed to give out phlogiston enough to ·ce the acid basis to a regulus, and to afford the ·mmable air which escapes. Or, in the other ·ry, it will be said that the zinc, having a strong ·dency to combine with vital air, and become cal-cined,

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cined, cannot decompofe water at a moderate temperature, unlefs an acid be prefent, to remove the coating of calx by folution as faft as it is formed, which mere water cannot do. This therefore is the firft confequence of the mutual action of water, zinc, and the acid; namely, vital air quits the water to unite with the zinc, and inflammable air flies off at the fame time that the acid combines with the calx of zinc. But of the two metallic bafes, which are here combined by the intermedium of vital air, the zinc has a ftrong tendency to calcination, and the arfenic to become revived: it appears therefore, from the facts, that the zinc, attracting the vital air moft ftrongly, becomes ftill more calcined, and confequently lefs foluble; while the arfenic is reduced by the lofs of its vital air. Whence it muft follow, that the metallic zinc which remains, being enveloped with calx of zinc and metallic arfenic, can no longer be acted on by the acid and water which ftill continue undecompofed. On this, and fimilar occafions, it cannot however be too often repeated to the chemical ftudent, that theories ought to be cautioufly followed, as of ufe in the arrangement of facts, and in directing the path to future inveftigations; that difcriminating phenomena ought to be earneftly fought after, becaufe of infinitely more value than the moft ingenious fpeculations; and that an attachment to fyftem, though it frequently gives life and energy to the exertions of genius, is in general a certain fource of prejudices, which difable the enquirer from purfuing the fearch after truth, and fix his mind upon words inftead of things.

Action of arfenical acid on zinc.

Theory.

Caution refpecting theories.

In

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In the dry way, when one part of the filings of zinc was mixed with two of the arſenical acid, and diſtilled, the maſs took fire, with a very bright inflammation, as ſoon as the retort became red hot. The veſſel was burſt by the exploſion; and in its neck were found regulus of arſenic, and flowers of zinc. This effect may be explained from the ſame conſiderations as were applied to the combuſtion which takes place, in like circumſtances, with iron.

Action of arſenical acid on zinc:

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Biſmuth is acted upon by the arſenical acid in digeſtion. Water precipitates a powder from the ſolution, which conſiſts of acid of arſenic, combined with calx of biſmuth. In the dry way, biſmuth is calcined by this acid, but not diſſolved; a little arſenic being ſublimed: and, if water be added to the cooled maſs, the acid is taken up, but the calx remains. Regulus of antimony is affected nearly in the ſame manner as biſmuth, in the humid way; but, in the dry way, an inflammation takes place at the time of fuſion. By digeſtion with cobalt, the acid of arſenic aſſumed a roſe colour; but much of the cobalt remained undiſſolved. The whole maſs being diſtilled to dryneſs, and fuſed, afforded glaſs of a violet colour, and ſemi-tranſparent. Nickel communicates a green colour to this acid by digeſtion; a quantity of green powder, mixed with arſenic, being precipitated: the arſenic may be ſeparated by a gentle heat. In the dry way, the acid combines with nickel, and forms a yellow maſs, with grey ſtreaks upon it, reſembling a vegetation. By boiling in water, the acid is taken up, and a yellow powder

— on biſmuth;

— on antimony:

— on cobalt:

— on nickel.

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left behind, confifting of a combination of nickel and arfenic, moft probably in the acid ftate: the arfenic is reduced with charcoal, but the nickel is not. Calx of manganefe is fcarcely acted upon by acid of arfenic; but, when the manganefe is partly or entirely reduced, it is diffolved in the humid way; and affords cryftals as foon as the acid is nearly faturated. The regulus, digefted with the arfenical acid, becomes covered with a white powder of arfenical calx. When one part of the regulus was mixed with two parts of the dry acid, and expofed to diftillation, the regulus was fublimed before the heat was fufficiently great to fufe the acid, and confequently no mutual action took place; but when the acid was firft fufed, and the regulus added fucceffively in fmall lumps, inflammation took place, and calx of arfenic was fublimed.

Action of arfenical acid on manganefe.

Combinations of regulus of arfenic.

Regulus of arfenic is foluble in unctuous oils, in a boiling heat: the folution is black, and has the confiftence of falve when cold *. Moft metals unite with arfenic; which moft probably exifts, in the reguline ftate, in fuch as poffefs the metallic brilliancy. The calx, more or lefs acidified, is common in many minerals.

Ufes of arfenic.

Arfenic is ufed in a variety of arts. It enters into metallic combinations wherein a white colour is required. Glafs manufacturers ufe it; but its effect

* On arfenic and its acid, confult Scheele's Effays, p. 143; Bergman's Effays, vol. ii.; Pelletier, in the Journal de Phyfique for 1782, &c. &c.

in

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n the compofition of glafs does not feem to be clearly explained. Orpiment and realgar are ufed as pigments. Some attempts have been made to introduce it into medicine; but, as it is known to be a moft violent poifon, it is probable that the fear of its bad effects may long deprive fociety of the advantages it might afford in this way.

CHAP.

CHAP. XII.

CONCERNING COBALT.

COBALT.

Characters of cobalt.

COBALT is a femi-metal, of a whitifh grey, or fteel colour; hard, brittle; of a dull, clofe-grained fracture, and moderate fpecific gravity. It is rather more difficult of fufion than copper; does not eafily become calcined; and its calx is of fo deep a blue colour, as to appear black. The moft remarkable and moft valuable property of this metallic fubftance is, that its calx, when fufed with borax, or with alkali and fand, produces a blue glafs, known by the name of fmalt. The action of air foon tarnifhes it; but water has little or no effect upon it.

Combination with vitriolic acid:

Concentrated and boiling vitriolic acid, diftilled nearly to drynefs, combines with this femi-metal. Much vitriolic acid air flies off; and the cobalt is in part calcined, and in part converted into a cryftallizable falt, foluble in water, and precipitable by lime and by alkalis in the form of a rofe-coloured powder or calx. Diluted vitriolic acid acts upon the calx of cobalt, and forms the fame falt.

— with nitrous acid.

Nitrous acid diffolves cobalt by the affiftance of a moderate heat. Nitrous air is difengaged; and the folution affords deliquefcent cryftals by evaporation, which do not detonate on ignited coals, but boil up and leave a red calx. Lime, and the alkalis, precipitate the folution; and, if the alkali be added in excefs, it diffolves the precipitate.

The

Combination with marine acid:

The marine acid has scarcely any action on co-
alt, unless it be boiling; in which case it dissolves a
nall portion. It dissolves the calx more readily;
ith which it forms a red brown fluid, that becomes
een when heated. This solution affords deliques-
nt crystals by evaporation.

— with aqua regia.

Aqua regia dissolves cobalt more easily than the
arine, though not so readily as the nitrous, acid.

Sympathetic ink.

his solution is well known, as one of the most cele-
ated sympathetic inks afforded by chemistry. If it
: diluted with a sufficient quantity of water to pre-
nt its action upon paper, and then used to write
ith, the letters are invisible as soon as the clear
lution has become dry: but, if the paper be held to
e fire for a short time, they appear of a fine green
lour; which again disappears by removing it, and
fiering it to cool again. If the heat be continued
o long after the letters appear, it will render them
rmanent. This effect seems to be analogous to
at which obtains in the marine solution: but none
the efficient causes of change of colour in this, or
y other chemical phenomenon, have been hitherto
plained.

Acid of borax and cobalt.

The acid of borax does not act immediately on
balt, in the humid way: but borax itself, added to
her of the foregoing solutions, effects a decompo-
ion by double affinity; the alkali uniting with the
lvent acid, while the acid of borax seizes the cobalt,
d forms a scarcely soluble compound, which falls
wn.

Acid of sugar.

The acid of sugar precipitates cobalt from its solu-
ons, in the form of a pale rose-coloured powder.

Whether

COBALT.

Habitudes of cobalt:

Whether alkalis or earths combine with this metal directly, by the intervention of water, has not been determined.

— with nitre: Cobalt does not act on neutral salts in general. It detonates feebly with nitre, when projected into a red hot crucible, with twice or thrice its weight of that salt. The metal becomes calcined by the action of the nitre; but the changes in both substances require farther examination.

— with sal ammoniac: Sal ammoniac is not decomposed by cobalt.

— with sulphur: Sulphur does not unite with cobalt, but with difficulty. Liver of sulphur combines more readily with it. The action of phosphorus, or its acid, on this substance, remains to be ascertained.

— with metallic substances. This semi-metal unites by fusion with most of the metals and semi-metals, as has before been noticed. Silver, lead, and bismuth, do not mix with it; and zinc does not but with great difficulty.

Native cobalt and its ores. Cobalt is found native in alloy with arsenic and iron, and of a steel-grained appearance when broken; or in a calciform state, of a black colour, either pulverulent or indurated: or combined with arsenical acid, in the flowers of cobalt, of a red colour; or, lastly, united to sulphur and iron, with or without arsenic, of various shades of redness. Bismuth, nickel, and other substances, are contained in these ores. They may in general be distinguished by solution in aqua regia; with which, after dilution with water, they form the sympathetic ink above described.

Humid analysis. The native cobalt, and its calciform or sulphureous ores, may be examined by solution in aqua regia, and evaporation to dryness; after which, the

calcined

COBALT.

Humid analysis of cobalt ores.

calcined cobalt may be dissolved by vinegar. When this calx is precipitated by mild mineral alkali, the regulus may be accounted for, by allowing one hundred grains for every hundred and sixty grains of precipitate. The other component parts of the residue, not taken up by the vinegar, may be ascertained by the methods described in the preceding chapters. The red arsenical cobalt ore, which contains arsenical acid, may be decomposed by vitriolic acid; and the disengaged arsenical acid will be taken up by highly-rectified spirit of wine; after which, the combination of vitriolic acid and cobalt may be dissolved in water, and precipitated by mild alkali: or the ore itself may be dissolved in water, sharpened by an acid; and the calx be then precipitated by the alkali.

Analysis in the dry way.

In the dry way, the ores of cobalt, after previous pounding, washing, and roasting, may be fused with three times their weight of black flux, in a lined and covered crucible, by the heat of a smith's forge. The tinging power of cobalt ores may be assayed by fusion with three parts of fixed alkali, and five of powdered flint, or glass. The alkali must be put first into the crucible; next, the flint; and, above all, the roasted ore. When cobalt ores, containing bismuth, are reduced, this semi-metal usually occupies the lower part of the crucible, and may be separated from it by a blow with a hammer; or at least by eliquation, or melting, on account of its greater fusibility.

Cobalt found most plentifully in Saxony.

Cobalt is found in several parts of Europe, but most plentifully in Saxony. The ore is usually broken

 into

COBALT.

Manufacture of zaffre and ſmalt.

into pieces about the ſize of a hen's egg, and the ſtony parts picked out. The ſorted mineral is then pounded in mills, and ſifted through wire ſieves. By waſhing in water, the lighter parts are carried off; and the remainder is calcined in a furnace reſembling an oven, wherein it is heated by the action of the reverberated flame of wood which plays upon it. In this ſituation, it is occaſionally ſtirred with long iron rakes; and emits fumes, conſiſting chiefly of arſenic, which is collected in a long horizontal chimney, built for that purpoſe. If the ore contain biſmuth, this fuſible ſemi-metal is collected at the bottom of the furnace. The cobalt, after a ſufficient torrefaction, remains in the form of a dark grey calx, called zaffre. The zaffre of commerce always contains twice or thrice its weight of powdered flints. The flint is pulverized, for this and other purpoſes, by means of previous ignition, and quenching in water, which renders it friable. Smalt is a blue glaſs, compoſed of one part of the calcined cobalt, fuſed with two of the flint powder, and one of potaſh. Powder blue, or azure, is obtained by grinding ſmalt in mills, and afterwards waſhing it in water. This laſt operation is performed in a caſk filled with water, and pierced with three openings at different heights. The water of the uppermoſt cock carries out the fineſt blue, which they call azure of the firſt fire. The larger particles fall more ſpeedily, and the azure brought out by the water of the three cocks forms the different degrees of fineneſs known under the names of azure of the firſt, ſecond, and third fires.

The

COBALT.

Uses of cobalt.

The uſe of this metallic ſubſtance is confined chiefly to the production of the blue glaſs for enamels, and other purpoſes. Powder and ſtone blue, uſed by laundreſſes, is a preparation made by the Dutch from the coarſe ſmalt.

CHAP. XIII.

CONCERNING ZINC.

ZINC. Characters of zinc.

ZINC is a femi-metal, of a blueifh white colour, fomewhat brighter than lead; of confiderable hardnefs; and fo malleable, as not to be broken with the hammer, though it cannot be much extended in this way. It is very eafily extended by the rollers of the flatting mill. When broken by bending, its texture appears as if compofed of cubical grains. On account of its imperfect malleability, it is difficult to reduce it into fmall parts by filing or hammering: but it may be granulated, like the malleable metals, by pouring it, when fufed, into cold water; or, if it be heated nearly to melting, it is then fufficiently brittle to be pulverized. It melts long before ignition, at about the 700th degree of Fahrenheit's thermometer; and, foon after it becomes red hot, it burns with a dazzling white flame, of a blueifh or yellowifh tinge, and is calcined with fuch rapidity, that it flies up in the form of white flowers, called the flowers of zinc, or philofophical wool. Thefe are generated fo plentifully, that the accefs of air is foon intercepted; and the combuftion ceafes, unlefs the matter be ftirred, and a confiderable heat kept up. The white calx of zinc is not volatile, but is driven up merely by the force of the combuftion. When it is again urged by a ftrong heat, it becomes converted into a clear yellow

glafs,

glafs. If zinc be heated in clofed veffels, it rifes without decompofition. Zinc appears to be the moft volatile of metallic fubftances, except the regulus of arfenic. ZINC.

The diluted vitriolic acid diffolves zinc; at the fame time that the temperature of the folvent is increafed, and much inflammable air efcapes: an undiffolved refidue is left, which confifts of plumbago. The theories of this folution, and the difengagement of inflammable air, are perfectly fimilar to thofe which have been before explained in the chapter on iron. As the combination of the vitriolic acid and the calx proceeds, the temperature diminifhes; and the vitriol of zinc, which is more foluble in hot than cold water, begins to feparate, and difturb the tranfparence of the fluid. If more water be added, the falt may be obtained in fine prifmatic four-fided cryftals. The white vitriol, or copperas, ufually fold, is cryftallized haftily, in the fame manner as loaf fugar, which, on that account, it refembles in appearance: it is flightly efflorefcent. The white calx of zinc is foluble in the vitriolic acid, and forms the fame falt as is afforded by zinc itfelf. Solution of zinc in vitriolic acid. Page 296. White vitriol.

Diluted nitrous acid combines rapidly with zinc, and produces much heat, at the fame time that a large quantity of nitrous air flies off. The folution is very cauftic, and affords cryftals by evaporation and cooling, which flightly detonate upon hot coals, and leave a calx behind. This falt is deliquefcent. Solution of zinc in nitrous acid:

Marine acid acts very ftrongly upon zinc, and difengages much inflammable air; the folution, when evaporated, does not afford cryftals. —in marine acid.

ZINC.

Water impregnated with fixed air diffolves a confiderable proportion of zinc. The other acids have not been tried.

Habitudes of zinc:

Zinc is precipitated from acids, by the foluble earths, and the alkalis: the latter rediffolve the precipitate, if they be added in excefs.

— with vitriolic falts:

Zinc decompofes, or alters, the vitriolic neutral falts in the dry way. When fufed with vitriolated tartar, it converts that falt into liver of fulphur; the zinc at the fame time being calcined, and partly diffolved in the hepar. In this operation, the vital air of the acid combines with the zinc, and calcines it; at the fame time that, according to the ancient theory, the phlogifton of the metal combines with the acid bafe, and converts it into fulphur. In the new theory, the tranfition of phlogifton is confidered as hypothetical and unneceffary: becaufe, the metal and the fulphur being taken to be fimple fubftances, the vitriolic acid becomes fulphur, merely by the lofs of its vital air; and the zinc becomes calcined, merely by the acquifition of the fame fubftance.

— with nitre:

When pulverized zinc is added to fufed nitre, or projected together with that falt into a red hot crucible, a very violent detonation takes place; infomuch that it is neceffary for the operator to be careful in ufing only fmall quantities, left the burning matter fhould be thrown about. The zinc is calcined; and part of the calx combines with the alkali, with which it forms a compound, foluble in water.

— with common falt; fal ammoniac; and alum.

Zinc decompofes common falt, and alfo fal ammoniac, by combining with the marine acid. The filings of zinc likewife decompofe alum, when boiled in a

folution

folution of that falt, probably by combining with its excefs of acid.

ZINC.

Habitudes of zinc with fulphur:

Sulphur, though its action is almoft general on metallic fubftances, does not combine with zinc. This property affords a ready means of purifying the femi-metal, by projecting fulphur upon it, when melted in a fhallow crucible. It has been a fubject of remark, among chemifts, that many of the zinc ores confift of this femi-metal combined with fulphur, though art has not yet difcovered the means of effecting the fame combination. But the difficulty is removed by the confideration, that the fulphur does not unite with zinc itfelf, yet it readily does with its calx, and forms a compound fimilar to the zinc ores, called blendes; in which, for that reafon, the zinc may be prefumed to exift in the calciform ftate.

— with liver of fulphur:

Liver of fulphur does not combine with zinc, either in the humid or dry way.

— with metals.

Moft of the metallic combinations of zinc have been already treated of. It forms a brittle compound with antimony; and its effects on manganefe, wolfram, and molybdena, have not yet been afcertained.

Native zinc and its ores.

Native zinc has been very feldom found. The calciform ores of zinc are the zinc fpar, of a whitifh grey colour, refembling a lead fpar; and the impure calx called calamine, which is of a white, grey, yellow, brown, or red colour, containing iron, clay, calcareous and other earths, and lead. The ore called blende, mock lead, or black jack, confifts of zinc mineralized with fulphur and iron: of this there are feveral varieties. They are in general of a plated texture; and frequently of a quadrangular

 form,

ZINC.

form, like galena, or potters' lead ore, though they are confiderably lefs heavy. Thefe ores are found in various parts of Europe; and, in confiderable plenty, in the mine counties of England.

Humid analyfis of zinc and its ores.

Native zinc may be affayed, in the humid way, by the mineral acids. When it is diffolved in thefe, if there be any other metal prefent, it may be precipitated by the addition of a known quantity of zinc. The weight of calx of zinc precipitated by mild alkali from its vitriolic folution, will amount to 193 grains for every 100 of the metal it reprefents. The fulphureous zinc ores muft be carefully treated with nitrous acid; which will diffolve the zinc, and leave the fulphur. Extraneous metals may be precipitated, and the quantity of zinc afcertained, as before.

Effay of calamines.

The effay of calamines is fometimes made by pounding and mixing them with charcoal, and then heating them in a crucible covered with a copper plate. The reduced zinc rifes, and converts the copper into brafs; and, in this way, fome judgment may be formed of its value in the operation of brafs-making. Moft of the zinc, whether in the metallic ftate, or in the form of an impure calx, called cadmia fornacum, is obtained in the roafting of various kinds of ores at Ramelfburg. For this purpofe, the anterior part of the furnace is kept cold by wetting it: by which means the volatilized zinc is condenfed, and falls into a cavity, containing charcoal duft, which defends it from calcination.

Diftillation of zinc.

The procefs for obtaining zinc from its ores by diftillation, which is practifed in England, and faid to have originally been derived from the Chinefe, is performed

performed in a furnace, in the form of a circular oven; in which are placed six pots, each about four feet in height, and of a conical shape, resembling an oil jar. Into the bottom of each pot an iron tube is inserted, which passes through the floor of the furnace into a vessel of water. These pots are filled with a mixture of calamine and charcoal; and their mouths are then close stopped with clay. The fire being then properly applied, the metallic vapour of the calamine issues through the iron tube, which is the only place where it can escape. In this way it is condensed in small particles in the water; which are afterwards melted into ingots for sale, under the name of spelter *. The substance sold in London by the name of spelter, is a kind of soft brass, in a granulated form, which is used by the braziers and others for soldering.

ZINC. Distillation of zinc.

Spelter.

The chief purpose to which zinc is applied consists in the fabrication of brass, and other gold-coloured mixtures. Its calces and salts have been occasionally employed in medicine.

Use of zinc. Page 288.

* Watson's Chemical Essays, vol. iv.

CHAP.

CHAP. XIV.

CONCERNING ANTIMONY.

ANTIMONY. Characters of antimony.

REGULUS of antimony is of a ſilvery white colour; very brittle, and of a plated or ſcaly texture. Its ſpecific gravity is moderate. Soon after ignition it melts; and, by a continuance of the heat, it becomes calcined, and riſes in white fumes, which may afterwards be volatilized a ſecond time, or fuſed into a hyacinthine glaſs, according to the management of the heat: they are called argentine flowers of regulus of antimony. In cloſed veſſels, the regulus riſes totally without decompoſition. This metallic ſubſtance is not ſubject to ruſt by expoſure to air; though its ſurface becomes tarniſhed by that means. Its calces are ſoluble in water; and, in that reſpect, reſemble the calx of arſenic, probably by an approach towards the acid ſtate.

Action of vitriolic acid on antimony.

Vitriolic acid, boiled upon the regulus of antimony, calcines the greater part, ſo as to render it inſoluble; the acid being at the ſame time decompoſed. Much vitriolic acid air eſcapes; and, towards the end, a ſmall quantity of ſulphur is ſublimed. By waſhing the reſidue in water, a vitriolic ſalt of antimony is ſeparated from the calx, which does not cryſtallize.

Nitrous acid.

Nitrous acid very readily attacks antimony in the cold. Moſt part of the metal is calcined by this action; but a portion is diſſolved, and affords deliqueſcent cryſtals, decompoſible by heat. The calx of

ANTIMONY.

of antimony formed by this acid, is very white, and difficult of reduction.

Solution of antimony in marine acid:

Continued digeftion is required for the folution of regulus of antimony in the marine acid. A confiderable quantity is however at length diffolved; which affords very deliquefcent cryftals. This falt melts by the application of heat; and is decompofed by diftilled water, in the fame manner as the butter of antimony, from which it does not much differ.

— in dephlogifticated or aerated marine acid:

Dephlogifticated or aërated marine acid diffolves the regulus of antimony with great facility.

— in aqua regia.

Aqua regia, compofed of feven parts nitrous, and one marine acid, diffolves it very readily; but lets fall a portion of white calx as it cools. The folvent power of either of the three ancient mineral acids on this femi-metal, appears to be increafed by mixture with any one of the others.

Habitude of regulus of antimony with earths:

Earthy fubftances do not act on the regulus of antimony in the dry way. Its calx, however, enters readily into the compofition of glafs; to which it imparts more or lefs of an hyacinthine colour. When fufed with vitriolated tartar, it converts it partly into hepar, or liver of fulphur; which diffolves a portion of the calx of antimony: that is to fay, the vital air of the acid calcines the regulus of antimony, while part of the acid becomes converted into fulphur; either fimply by the lofs of its vital air, or elfe by that lofs, together with the acquifition of phlogifton from the regulus.

— with vitriolated tartar.

Detonation with nitre.

Nitre detonates very readily with the regulus of antimony: when equal parts of thefe fubftances are projected into a red hot crucible, the refidue of calx and alkali is known by the name of diaphoretic anti-

7 mony.

ANTIMONY. mony. When the ſaline part is waſhed out by hot water, the reſidue is called waſhed diaphoretic antimony. The water uſed in the waſhing contains a portion of the calx, ſuſpended by the alkali. This may be precipitated by the addition of an acid, and has been diſtinguiſhed by the name of ceruſe of antimony.

Diſtillation of regulus of antimony with corroſive ſublimate.

When regulus of antimony is pulverized, and accurately mixed with about twice its weight of corroſive ſublimate, a mutual action takes place with the production of heat; and, if the mixture be diſtilled with a gentle fire, a thick fluid comes over, which congeals in the receiver, or in the neck of the retort, and is called butter of antimony. The reſidue conſiſts of revived mercury, and ſome regulus and calx of antimony. In this experiment, the dephlogiſticated marine acid combines with the antimony, while the mercury is revived; as may be eaſily explained on either of the two theories of chemiſtry. If the combination of regulus of antimony and ſulphur be uſed inſtead of the regulus itſelf, the mercury will be obtained in the form of cinnabar, at a much greater heat than is required to ſublime the butter of antimony.

Butter of antimony.

Theory.

Powder of algaroth.

When butter of antimony is thrown into pure water, an abundant white precipitate, or calx, falls down, which is a violent emetic, and is known by the name of powder of algaroth.

Bezoar mineral.

Nitrous acid diſſolves the butter of antimony. The ſolution, which does not appear to differ greatly from the ſolution of the regulus in aqua regia, ſoon depoſits a portion of calx. When an equal weight of nitrous

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itrous acid has been three times diſtilled to dryneſs om butter of antimony, the reſidue, after ignition, called bezoar mineral; and ſeems to be little more han a calx of the metal.

Combination of regulus of antimony with ſulphur:

Sulphur combines very readily with the regulus of ntimony, and forms a ſubſtance differing in no reect from the mineral, or ore, to which the name of ntimony is excluſively appropriated. One part of lphur completely mineralizes four of the regulus.

— with liver of ſulphur.

Liver of ſulphur diſſolves the regulus of antimony, d affords an orange-coloured precipitate upon the ldition of an acid.

Crude antimony:

Antimony, or the regulus combined with ſulphur, as a favourite object of reſearch in the experiments the alchemiſts; in conſequence of which, its properties are much better known than thoſe of the pure gulus. If this ſubſtance be heated, it melts, and conſiderable portion of the ſulphur flies off, at the me time that the regulus becomes calcined, and ſes in white vapours. A gentler heat, leſs than is eceſſary to fuſe it, converts it into a grey calx: is calx contains a portion of ſulphur. If it be rged by a ſtronger heat, it melts into the form of aſs, which is more or leſs tranſparent, according the degree of calcination of the metal, and the iſſipation of the ſulphur. When it contains much lphur, the glaſs is fuſible, opake, and of a dark d colour; whence it has been called liver of antiony.

— its habitudes: by heat:

— with acids.

When acids are applied to crude antimony, they iſſolve the regulus, and leave the ſulphur. The itrous acid is beſt adapted to this ſolution.

Diapho-

ANTIMONY.

Diaphoretic antimony.

Diaphoretic antimony is moſt commonly and advantageouſly prepared by detonating the crude antimony with nitre inſtead of the regulus: the only difference being, that more nitre is required for the detonation; and that the reſidue contains vitriolated tartar, as well as alkali and calx.

Antimonial medicines.

There are ſeveral preparations, conſiſting of combinations of antimony with an alkali, in which the proportions of the ingredients, and the ſtate of the calx, are very different, according to the nature and management of the proceſſes. Many of theſe have been highly praiſed in medicine; at the ſame time that they have been as ſtrongly exclaimed againſt for their ill effects. Both theſe aſſertions appear to have been well founded. It is ſufficiently proved that antimonial medicines have produced the happieſt effects, and are juſtly entitled to be conſidered as very powerful remedies; but, on the other hand, it is equally certain, that their great efficacy muſt have required greater attention, in their firſt exhibition, than perhaps may have been paid; and the complicated nature of many of the proceſſes muſt have rendered it very difficult to produce ſubſtances poſſeſſing exactly the ſame properties, or proportion of component parts, at all times.

Kermes mineral.

If antimony be treated with a fixed alkali, either by fuſion and ſubſequent ſolution in boiling water, or by ſimple ebullition, a precipitate is afforded by cooling, which is called kermes mineral, formerly uſed in medicine. It is thought to conſiſt of the calx of antimony, in combination with a portion of ſulphur; but its component parts have not been accurately determined,

and

and its properties differ according to the various methods used in preparing it.

Antimonial medicines.

The antimonial preparations most commonly used at present are, antimonial wine, and emetic tartar. These, like every other preparation of this semi-metal, are prepared in a variety of ways. The wine may be had by infusing pulverized glass of antimony in Spanish white wine for some days, and then filtering the clear fluid through paper. A very minute portion of the calx is taken up; and this is greater or less, according as the wine is more or less acid; and perhaps, according to the temperature of the weather at the time of administering it. On this account, it is found necessary to give this medicine cautiously, and by small portions at a time, when it is intended that it shall act as an emetic. The emetic or antimoniated tartar of the London College is thus prepared:—Take of crude antimony and nitre equal parts, separately reduced to powder; mix them, and inject them into a crucible heated to whiteness, that the mixture may melt after deflagration; pour it out, and reserve the yellow mass beneath the scoriæ, under the name of crocus of antimony; reduce this to a very subtile powder; boil it in water, and wash the powder repeatedly in warm water, till it becomes perfectly insipid: then take equal parts, by weight, of the washed crocus of antimony and of crystals of tartar, and boil them together, in three pints of water for every pound of the mixture, during half an hour: filter the liquor; and, after due evaporation, set it by to crystallize.—This is the antimoniated tartar. It is a triple salt, consisting of the acid of

Emetic wine.

Antimoniated tartar.

tartar,

ANTIMONY. tartar, united to vegetable alkali, and antimony partially calcined; and is confidered as a fafe medicine, whofe properties and effects are more conftant, and milder, than moft other antimonial remedies.

Medical effects of antimony.

It has not been clearly determined on what circumftances the medical effects of antimony depend. The faline preparations of mercury, and other metals, are fuppofed to derive their caufticity from their tendency to become reduced to the metallic ftate; in confequence of which, they corrode and decompofe other combuftible fubftances: but whether this be the cafe with antimony, is doubtful. It appears neceffary, however, that antimony fhould be in the faline ftate, in order that it may act upon the animal fyftem. When the regulus is made into thofe fmall balls or pills, which, on account of the little change they undergo in paffing through the human body, have been called perpetual pills, its purgative action is more or lefs violent, according to the quantity of acid it meets with; and, in the preparations of this femi-metal, their effects feem likewife to be governed by the fame circumftance joined to their refpective degrees of folubility. The nearly pure and infoluble calx, produced by detonation with a large proportion of nitre, is almoft ineffectual; whereas the more foluble calces or combinations are more or lefs active, according to their refpective nature. Hence it appears to follow, that the fimpleft faline combinations are the moft likely to produce effects conftantly fimilar; and that moft of the calces and combinations, fo highly extolled in the earlier age of chemiftry, are attended with dangerous uncertainty in their operation.

Perpetual pills.

Antimony

ANTIMONY.

Antimony combines with moſt other metallic ſubſtances, and produces mixtures whoſe properties have been attended to under their reſpective titles.

Native antimony and its regulus.

Antimony is found either native, in maſſes of the regulus, compoſed of ſhining irregular plates; or calciform, in white cryſtallized filaments; or combined with ſulphur, in the dark blueiſh or grey friable mineral, called antimony, conſiſting moſt commonly of brilliant filaments diſpoſed parallel to each other; or, laſtly, combined with ſulphur and arſenic, in an ore which greatly reſembles the foregoing, except that it is of a red or reddiſh colour.

Humid analyſis.

Native regulus of antimony, or its calx, may be aſſayed by nitrous acid, which diſſolves whatever arſenic it may contain, and only calcines the antimony. The ſulphureous antimonial ores are moſt conveniently analyſed by aqua regia, which takes up the calx, and leaves the ſulphur, which may be ſeparated by filtration. The remaining ſolvent may be examined with the uſual precipitants. In the dry way, antimony is ſeparated from its ſtony parts by fuſion in a moderate heat, nearly in the ſame manner as biſmuth; and may be reduced, by ſlowly roaſting it, till it becomes converted into a grey calx, which may be briſkly fuſed with twice its weight of black flux.

Dry way.

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Uſes.

Antimony and its regulus are chiefly uſed in medicine, and in ſome metallic alloys, ſuch as that uſed for printers types, ſmall ſhot, &c.

CHAP. XV.

CONCERNING MANGANESE.

MANGANESE. Characters of manganese.

THE regulus of manganese is a semi-metal of a dull whitish colour when broken, but soon grows dark by calcination from the action of the air. It is hard, brittle, though not pulverable, and rough in its fracture; so difficultly fusible, that no heat yet exhibited has caused it to run into masses of any considerable magnitude; and appears to be more disposed to calcination than any other metallic substance, unless we may except wolfram. Its calces are white when imperfect; but black, or dark green, when perfect: the white are soluble in acids. When broken in pieces, it falls into a powder by spontaneous calcination; and this powder is magnetic, though the masses were not possessed of that property. It seems as if the regulus of manganese were capable of depriving a small proportion of iron of its magnetism; but that the effect ceases as soon as that regulus is converted into calx. A strong heat expels vital air from the calx of manganese.

Concentrated vitriolic acid attacks the regulus of manganese, but much more readily when diluted with two or three times its weight of water; at the same time that inflammable air is disengaged. A black spongy substance remains undissolved, which has not been examined. The solution is colourless, and affords crystals

MANGANESE.

cryſtals by evaporation. Mild alkalis precipitate a white calx, ſoluble in acids; but pure alkalis afford a brown calx, which ſoon grows black in the air, and is ſcarcely ſoluble. The black calx of mangancſe, when old, or well made, is altogether inſoluble in acids, unleſs ſome combuſtible ſubſtance be added. It appears therefore that the metal in this ſtate is too far calcined, and requires to be reduced again in a certain degree towards the metallic ſtate, to be diſſolved. If vitriolic acid be added, and drawn off by diſtillation ſeveral times from the black calx, by an heat nearly approaching to ignition, in a glaſs veſſel; it is found that vital air is diſengaged towards the end of each proceſs, and part of the calx is diſſolved. The ſolution of the calx in acids, by the addition of combuſtible matter, is eaſily accounted for, on either of the theories of chemiſtry, by affirming that the reduction is effected by the addition of phlogiſton, or the ſubtraction of vital air from the calx by means of the combuſtible ſubſtance. The phlogiſtic theory appears however to be deficient, in explaining the ſolution by mere vitriolic acid, at an elevated temperature *, on account of the abſence of phlogiſton; but the new theory ſimply aſſerts the facts, that the calx loſes vital air in conſequence of the elevated temperature, and is rendered ſoluble in the acid.

Black calx of manganeſe.

Theory.

* Bergman, ii. 215 (on the hypotheſis, that heat is matter; that this matter conſiſts of pure air united to phlogiſton; and that manganeſe decompoſes the heat), derives the phlogiſton required for the ſolution, as well as the vital air which flies off, from this decompoſition. Theſe poſitions did not appear ſufficiently grounded to enter the text.

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Solution of regulus of manganese in nitrous acid:

Nitrous acid dissolves the regulus of manganese with effervescence, and the escape of nitrous air. A spongy, black, and friable matter remains, whose properties resemble molybdena. The solution does not afford crystals. The perfect calx is not soluble in pale nitrous acid, unless some combustible matter be added.

— in marine acid.

The regulus is dissolved in the usual manner by marine acid. The black calx is likewise soluble; but adheres so weakly to the acid, as to be separated even by the mere addition of water: but, if this solution be exposed to a digesting heat for some hours, an intestine motion, like an effervescence, takes place; the smell of dephlogisticated or aërated acid is perceived; and the combination becomes more perfect, so as not to afford a precipitate, unless an alkali be added. Marine acid dissolves the black calx also, by the addition of a combustible substance. Mercury, and even gold, will effect this combination. The solution of manganese in marine acid scarcely affords crystals, but a deliquescent saline mass by evaporation, which is soluble in ardent spirit.

Explanation.

In the permanent solution of black calx of manganese by marine acid, it is seen that the acid itself must communicate the property to the calx, on which its solubility depends; that is to say, it must either afford phlogiston, or absorb vital air: and accordingly, the red vapours which escape are distinguished by the name of dephlogisticated, or aërated, marine acid, according to the theory which may be adopted by the speaker.

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Other acids likewife diffolve this metallic fubftance. The fluor acid, and alfo the phofphoric acid, form compounds of difficult folubility, which envelope and defend it from their farther action in a fhort time.

Combinations of calx of manganefe in the dry way.

In the dry way, the calx of manganefe combines with fuch earths and faline fubftances as are capable of undergoing fufion in a ftrong heat. Thefe experiments are moft advantageoufly performed by the blow-pipe, on fmall quantities of matter; becaufe, in this way, the whole of the phenomena are clearly feen. The moft remarkable property of the folutions is, that a due proportion of combuftible matter renders them colourlefs; for which reafon, the calx of manganefe is ufed by the glafs manufacturers, to deftroy the colours of glafs. If a globule of microcofmic falt be fufed by the blow-pipe upon charcoal, and a fmall portion of the black calx of manganefe be added, the colour will be of a blueifh red; or of a deep red, if the quantity of calx be greater. If the fufion be continued by the interior blue flame, the colour at length difappears; but may be eafily revived again, by foftening the globule with the exterior flame. A fmall particle of nitre inftantly reftores the red colour; but inflammable matter, or vitriolic falts, contribute to difcharge it. If the globule, after being deprived of all colour, be fufed in the filver fpoon, it recovers its rednefs; and the colour is not difcharged by any management of the fufion, unlefs fome inflammable matter be added.

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Changes of colour.

Explanation.

Thefe remarkable changes of colour, which may be repeatedly produced, depend evidently on the prefence or abfence of combuftible matter; or, which amounts

MANGANESE. to the fame thing, on the degree of calcination of the manganefe which is held in folution. When the highly calcined or black manganefe is firft added, it produces a coloured globule; if inflammable matter be added, the calx is partly reduced, and forms a colourlefs combination. Nitre reftores the colour by its well-known property of calcining metals. When the fufion is performed by the interior flame, the globule may be confidered as if heated in a clofe veffel, in contact with charcoal; becaufe the furrounding flame prevents the accefs of air: a revival of the calx therefore enfues, and the colour vanifhes. But when the external flame is ufed, its apex, or point only, touches the globule; and the furrounding air promotes or maintains the calcination more effectually than the charcoal can produce the contrary effect: the confequence therefore is, that the colour again appears. Vitriolic falts feem to forward the action of the charcoal, which converts them into fulphur; and the colour remains fixed in the fpoon, becaufe there is no combuftible fubftance prefent, which is fufficiently fo to promote the revival of the calx. It is evident that both the theories of chemiftry are applicable to thefe facts, whether the charcoal revives the calx by phlogifticating it, or by depriving it of its vital air; or whether the calcination by the apex of the flame be effected by the diffipation of phlogifton, or by the abforption of vital air from the atmofphere.

Explanation of the changes of colour in glaffes which contain manganefe.

Theories.

Nearly fimilar changes are produced when the calx is fufed with borax, or an alkali.

Combination with fulphur.

Regulus of manganefe does not appear to combine with fulphur; but eight parts of the calx combine with

MANGANESE.

with three of ſulphur, and produce a yellowiſh green maſs, which is acted upon by acids; the metal being diſſolved with effervefcence, and the diſengagement of hepatic air. The remaining ſulphur may be collected on a filter.

Metallic combinations of manganeſe.

This ſemi-metal melts readily with moſt of the other metals, but rejects mercury. Gold and iron are rendered more fuſible by a due addition of manganeſe; and the latter metal is rendered more ductile. Copper becomes leſs fuſible, and is rendered whiter, but of a colour ſubject to tarniſh *.

Native manganeſe and its ores.

Regulus of manganeſe has been found native among the powdery or calciform ore of this metallic ſubſtance. Its properties, in this ſtate, perfectly reſemble the regulus produced by art. Manganeſe appears to exiſt in the calcined ſtate in all its ores; though contaminated with admixtures of earths, or other metallic matters. They are, white, red, brown, or black; either pulverulent, indurated, or cryſtallized. Vegetable aſhes likewiſe afford indications of manganeſe.

Humid analyſis.

To analyſe the ores of manganeſe in the humid way, they muſt be reduced to a ſubtile powder, and immerſed in a mineral acid, with a piece of ſugar to aſſiſt the ſolution. If nitrous acid be repeatedly abſtracted to ignition from the ore, the iron it contains will be rendered nearly inſoluble from calcination; and the manganeſe may be taken up by ſtrong concentrated vinegar, or diluted nitrous acid. This, when precipitated by mild mineral alkali, affords 180

* Annales de Chimie, i. 303.

MANGANESE. grains of precipitate for every 100 grains of regulus: or if the metals be precipitated from superabundant nitrous acid, by Prussian alkali, the manganese will be totally dissolved by pure water, while the iron remains behind.

Spontaneous inflammation of black wadd.

The ore of manganese, which is known in Derbyshire by the name of black wadd, is remarkable for its spontaneous inflammation with oil. It is of a dark brown colour, of a friable earthy appearance, partly in powder, and partly in lumps. If half a pound of this be dried before a fire, and afterwards suffered to cool for about an hour; and it be then loosely mixed or kneaded with two ounces of linseed oil; the whole, in something more than half an hour, becomes gradually hot, and at length bursts into flame. This effect wants explanation. It seems, in some measure, to resemble the inflammation of oils by the nitrous acid.

Page 165.

Reduction of manganese.

The presence of manganese may be ascertained in the dry way, by the blow-pipe, from the singular changes of colour already described, when fused with microcosmic salt, or borax. The reduction of the ore is effected by mixing it with pitch, making it into a ball, and putting it into a crucible lined with powdered charcoal, one tenth of an inch thick at the sides, and one quarter of an inch thick at the bottom; then filling the empty spaces with powdered charcoal, and luting on a cover. This must be exposed to the strongest heat of a forge, or furnace, for an hour, or more. As the calx of manganese is strongly disposed to vitrification, fluxes rather impede than forward the reduction. The reduced globules of manganese

MANGANESE.

Speedy calcination.

..nese are usually enveloped with a vitrified crust, ..hich either partly, or completely, defends them from ..e action of the air; but, when they are broken, ..ey lose their metallic brilliancy and consistence in a ..ry short space of time.

Uses of manganese.

Page 176.

Manganese has hitherto been used chiefly by glass-..akers and potters; but the important discoveries of ..e uses of dephlogisticated or aërated marine acid ..ll, no doubt, extend its utility to several other ma-..factories *.

* On manganese, consult Scheele, 67—142; Bergman, ii. ..1—225; the Memoirs of Pelletier, Berthollet, &c.; and the ..stracts by Elementary Writers on Mineralogy.

CHAP.

CHAP. XVI.

CONCERNING WOLFRAM.

WOLFRAM.
Page 216.

TUNGSTEN and wolfram have already been treated of in the section on acids; and the combinations of metals with the regulus of wolfram have been occasionally mentioned under their respective heads. Little else remains therefore to be said of this metallic substance, than to specify its general characters.

Characters and habitudes of the calx and regulus of wolfram.

The yellow matter, or calx of wolfram, turns blue by exposure to light; and more intensely, if to the light of the sun. By a strong heat in a covered crucible, it becomes of a blueish black colour, with loss of weight; which it recovers, together with its original yellow colour, by calcination, with access of air. These changes to the blue colour appear therefore to be partial reductions *. One hundred grains of the yellow calx, or acid, being put into a crucible with charcoal powder, well covered, and exposed to a strong heat, became converted into a button of a dark brown colour, and friable, with a diminution of forty grains of the original weight. Its specific gravity was 17.6; and, upon examination with a glass, a congeries of metallic globules was seen, some of them of the size of a pin's head; which, when broken, exhibited a fracture resembling steel. Part of this mass

* De Luyarts on Wolfram, page 58.

bei-

WOLFRAM. Habitudes:

ing calcined, became yellow as at firſt, and gained venty-four per cent. in weight. It was not ſoluble vitriolic or marine acid; but the nitrous acid, and ua regia, converted it again into the yellow calx. he yellow calx itſelf could not be vitrified. Acetous id converted the yellow colour to a blue.

—with ſulphur.

When equal parts of ſulphur and the yellow calx ere urged by a ſtrong heat, a blue friable maſs reained, weighing leſs than one-fourth of the whole.

CHAP.

CHAP. XVII.

CONCERNING MOLYBDENA.

MOLYBDENA.

Characters of regulus of molybdena.

MOLYBDENA, like manganese and wolfram, has not been reduced into masses of any considerable magnitude; but has been obtained only in small separate globules, in a blackish brilliant mass. It has been revived by a process similar to that by which regulus of manganese is obtained; but it requires a most extreme degree of heat for that purpose. The globules are grey, brittle, and extremely infusible. By heat it is converted into a white calx, which rises in brilliant needle-formed flowers, like those of antimony. Nitrous acid readily calcines and acidifies the regulus. Nitre detonates with it, and the remaining alkali combines with its calx.

Habitudes with various substances. See also p. 215.

Detonation with nitre decomposes the native molybdena; but solution in nitrous acid is the readiest way to procure the acid of this substance. Prussian alkali, and also infusion of galls, precipitate the acid from its solutions. When acid of arsenic is heated with molybdena, it converts part of the sulphur into volatile vitriolic acid; which comes over, and combines with another portion, with which it rises in the form of orpiment. No other acids but the nitrous and arsenical have any action on crude molybdena.

The

MOLYBDENA.

The regulus of molybdena unites with several of the metals, and forms brittle or friable compounds.

Distinctive characters.

This mineral is scarce. It is distinguishable from black lead by its more shining scaly appearance, and marks paper with a more brilliant stroke; and, as it resembles no other substance, it does not require to be assayed.

CHAP.

CHAP. XVIII.

CONCERNING URANITE, OR URANIUM.

METALLIC SUBSTANCES.

Uranite, or uranium.

THE celebrated profeffor Klaproth has detected a new metallic fubftance in the mineral ufually diftinguifhed by the name of pech-blende, or pitch-blende, and ranged among the ores of zinc. As it is not reducible but with the moft extreme difficulty, and then only into minute grains, it appears of little confequence to enter into any formal defcription of its metallic ftate: for which reafon, I fhall follow the order of the profeffor's analyfis in the prefent chapter *.

Defcription of pitch-blende.

The pitch-blende, or ore of uranite, is found in maffes, or elfe ftratified with other earths or minerals in the Swedifh and Saxon mines. It confifts of two varieties: the firft in maffes of a blackifh colour, inclining to a deep fteel grey, of little brilliancy; its fracture is unequal and concave in the fmalleft parts. It is perfectly opake, confiderably hard, and becomes convertible into a black powder by trituration. Its mean fpecific gravity is about 7.5. The fecond variety is ufually found in ftrata, and is diftinguifhed from the former by a deeper black colour, intermixed with fpots of red; its colour is more fhining, and

* Journal de Phyfique, April 1790.

approaches

pproaches that of coal; it is lefs hard, and, when ulverized, it has a greenifh tinge.

Habitudes by fire.

This mineral fuffers no change before the blow-ipe. With mineral alkali it affords a fpongy, femi-pake, grey globule. With microcofmic falt it melts, nd affords a green tranfparent globule; and in both here are fometimes feen fmall globules of reduced ad. When the mineral is heated alone, in a proper effel, it gives out fulphureous acid and fulphur, with ofs of weight; but if be afterwards kept ignited for confiderable time beneath a muffle, it gains fome eight by calcination.

Action of acids on pitch-blende.

The vitriolic acid acts very imperfectly upon pitch-lende; but nitrous acid completely decompofes it, olding moft part in folution, while a fmall propor-ion of fulphur, and fome filiceous earth, fall down. Marine acid acts but imperfectly upon it; but aqua egia diffolves it, as well as the pure nitrous acid. This folution, after it had depofited a fmall quantity of corneous lead, afforded large tranfparent cryftals by repofe in the cold, which were of a faint yellowifh green colour, and of a figure not eafy to be afcer-ained.

Precipitates.

It was remarkable, that this fubftance was not precipitable from its folvents either by iron or zinc; but volatile liver of fulphur threw down a brownifh yellow precipitate. Nut-galls did not precipitate any thing, unlefs the fuperabundant acid were neutralized by an alkali; and, in this cafe, the precipitate by galls was of a chocolate brown.

Precipitates.

A diftinctive criterion of this metallic fubftance was, its brownifh red colour when feparated by Pruf-

3 fian

METALLIC SUBSTANCES.

ſian alkali; a circumſtance indeed common alſo to copper: but this laſt metal falls down in flocks, whereas the former is uniformly ſeparated through the whole fluid. Volatile alkali uſually precipitates it of a yellow colour, more or leſs obſcure, according to the purity of the mineral, or of the alkali. The two fixed alkalis, when pure, precipitate it completely in the form of a lemon-coloured calx. Mild alkalis afford a paler calx.

Yellow calx of pitch-blende.

The yellow precipitate is very ſoluble in acids, and affords cryſtals by combination with the vitriolic and acetous acids. Phoſphoric acid affords yellowiſh irregular flocks, ſparingly ſoluble in water. Alkalis do not diſſolve the yellow matter either in the dry or humid way.

Reduction.

Various attempts were made by the diſcoverer to revive it to the reguline ſtate. He triturated it with linſeed oil to the conſiſtence of a paſte, burned the oil in a roaſting teſt, then placed the remaining black powder in a crucible lined with charcoal, and well covered, and expoſed it to a violent heat; which operated a reduction of manganeſe in another crucible, but produced no other change in the calx of uranite than to render it ſoluble in nitrous acid, with effervеſcence, heat, and eſcape of nitrous air. This altered calx was then put into an aſſayer's teſt, covered with borax, and mixed with charcoal, and the lid luted on. The heat of a porcelain furnace reduced it into a coherent maſs, conſiſting of very ſmall metallic globules agglutinated together.

BOOK

BOOK II.

PARTICULAR CHEMISTRY.

SECTION IV.

OF MINERAL COMBUSTIBLE BODIES, AND THE DIAMOND.

CHAP. I.

OF MINERAL COMBUSTIBLE BODIES.

MINERAL COMBUSTIBLES.

Enumeration.

THE inflammable ſubſtances found in the mineral kingdom are—1. Inflammable air, called fire-damp in the mines. 2. Hepatic air, which abounds in many hot baths, in mines, and in the neighbourhood of volcanos. 3. Naptha; a fine thin, fragrant, colourleſs oil, which iſſues out of white, yellow, or black clays in Perſia and Media. This is highly inflammable, and is not decompoſed by diſtillation. It diſſolves reſins, and the eſſential oils of thyme and lavender; but is not itſelf ſoluble either in ſpirit of

MINERAL COMBUSTIBLES.

wine or æther. It is the lighteſt of all the denſe fluids; its ſpecific gravity being 0.708. 4. Petroleum, which is a yellow, reddiſh, brown, greeniſh, or blackiſh oil, found dropping from rocks, or iſſuing from the earth, in the duchy of Modena, and in various other parts of Europe and Aſia. This likewiſe is inſoluble in ſpirit of wine; and ſeems to conſiſt of naptha, thickened by expoſure to the atmoſphere. It contains a portion of the acid of amber. 5. Barbadoes tar, which is a viſcid, brown, or black inflammable ſubſtance, inſoluble in ſpirit of wine, and containing the acid of amber. This appears to be the mineral oil in its third ſtage of alteration. 6. Aſphaltum is a ſmooth, hard, brittle, inflammable ſubſtance, which melts eaſily, and burns without leaving any aſhes, if it be pure. It is ſlightly and partially acted on by ſpirit of wine and æther. 7. Mineral tallow, which is a white ſubſtance of the conſiſtence of tallow; and as greaſy, though more brittle. It was found in the ſea on the coaſts of Finland, in the year 1736; and is alſo met with in ſome rocky parts of Perſia. It is near one fifth lighter than tallow; burns with a blue flame and a ſmell of greaſe, leaving a black viſcid matter behind, which is more difficultly conſumed. 8. Jet, which is much harder than aſphaltum; ſuſceptible of a good poliſh, and glaſſy in its fracture. It is highly electrical, fuſible in a moderate heat, and inſoluble in ſpirit of wine. 9. Pit coal. Of this there are many varieties: they appear to conſiſt of petroleum, conſolidated with an earth, chiefly of the argillaceous kind. 10. Peat is a black inflammable earth, which is of a viſcid conſiſtence

Petroleum. Barbadoes tar. Aſphaltum. Mineral tallow. Jet. Pit coal. Peat.

ence when freſh, but hardens by expoſure to the air. 11. Turf conſiſts of mould, interwoven with the roots of vegetables. 12. Amber has been already treated of (198). It is inſoluble in water, and in ſpirit of wine; and no other acid but the vitriolic diſſolves it. By diſtillation it affords a ſmall portion of water, an oil of the nature of petroleum, and a peculiar acid. 13. Sulphur is very abundant in the mineral kingdom. It has before paſſed under our obſervation, on account of its affording the vitriolic acid by combuſtion. 14. Plumbago, or black lead.

MINERAL COMBUSTIBLES.

Turf. Amber.

Sulphur.

Plumbago.

General obſervations on the combuſtible ſubſtances found in the mineral kingdom.

When we attend to the inflammable ſubſtances found in the earth, or in the mineral kingdom, we may perceive that very few, and moſt probably none of them, can be truly ſaid to belong to it; but have been elaborated in the bodies of animals or vegetables. From the turf that is pared from the ſurface of the earth, and owes its inflammability to the roots of vegetables which are mixed with it, we may deſcend to the peat, or black earth, of the moors; in many ſpecimens of which, vegetable remains are ſtill perceptible; though in moſt they appear to be deprived of every appearance of their organic texture, their oily and inflammable nature only remaining: and from thence the tranſition to pit-coal is eaſy. For if we reflect on the vaſt revolutions which the earth has certainly undergone through a long courſe of ages, by means of which its ſurface has been broken, diſplaced, and inverted, from the actions of floods, earthquakes, and the great convulſions of nature cauſed by volcanic eruptions, it will be no improbable inference, that the thin, though extenſive,

MINERAL COMBUSTIBLES.

General obfervations on the combuftible matter found in the mineral kingdom.

ftrata of pit coal, as well as the exfudations of naptha, petroleum, and their modifications, have all arifen from the burying of extenfive woody tracts of the furface, fuch as are common in all uncultivated countries. And this probability will be reduced to a certainty, when we advert to the natural hiftory of pit coal, which is met with in all the various ftates of transformation. Whole trees are converted into pit coal, in fuch quantities together as to exhibit entire forefts; in which the roots, trunks, branches, bark, and even fpecies, are difcernible. Coal-pits and flate-quarries exhibit innumerable marks of impreffions of leaves, and other indications of their vegetable origin; and the analyfis of this combuftible fubftance tends ftill further to confirm this truth. On the other hand, if we attend to fuch inferences as chemical theory might point out from the facts around us, we fhall fee how fmall the probability is, that the mineral kingdom fhould, after a certain limited time, contain inflammable bodies, if they were not occafionally thrown into it, in confequence of the operations carried on within organized fubftances. For all inflammable fubftances, tending to decompofe the vital air of the atmofphere, would, in procefs of time, revert to the clafs of uninflammable bodies, if the operation of organized bodies, particularly of the vegetable kind, did not tend to difengage the vital air again, and render bodies combuftible, which were not fo when they became parts of thofe fubftances.

CHAP.

CHAP. II.

CONCERNING THE DIAMOND.

DIAMOND. Characters, &c. of the diamond.

THE diamond is a mineral which, on ſeveral accounts, appears worthy to compoſe an order by itſelf. It is found in a ſandy earth in the hither peninſula of India, in the iſland of Borneo, and in the Brazils. The form of the diamond, when perfect, is that of an eight-ſided priſm. There are alſo cubical diamonds, which are ſuſpected to be of a different nature from the others. Diamonds are of a lamellated texture; and may be eaſily ſplit by a blow in a proper direction. The conſent of mankind has fixed an immenſe value upon this ſtone*. The inimitable qualities

* The value of diamonds is reckoned by weight, at ſo much the carat. The carat uſed in this valuation is divided into four parts, called grains; but leſs than troy grains by one fifth: for 150 carats are equal to the troy ounce of 480 grains. Rough diamonds, without any flaw or blemiſh, are valued at two pounds ſterling the ſingle carat; and the expence of cutting amounts to 3¾ pounds the carat. The value is greatly diminiſhed if the diamond be imperfect, or of a bad figure; and it increaſes rapidly with the ſize. To find the worth of a rough diamond, its weight in carats muſt be ſquared, and multiplied by two, and the product will be pounds ſterling. A cut or finiſhed diamond is worth four times as much as one that is ſtill rough. Thoſe of the greateſt brilliancy are ſometimes valued at a higher rate; but this value has never been applied to ſtones of exceſſive magnitude. It does not appear

 that

DIAMOND.

Hardneſs and brilliance of diamonds:

qualities to which this preference is attached, are its hardneſs, which is ſuch that it eaſily cuts all other ſubſtances, and takes a moſt exquiſite and laſting poliſh; and its very great refracting power, which is ſuch as to occaſion all the light to be reflected, which falls on any of its interior ſurfaces at a greater angle of incidence than $24\frac{1}{4}$ degrees. Hence its luſtre, when cut into the form of a regular ſolid, is very great. This may be eaſily underſtood, when it is conſidered that an artificial gem of glaſs does not reflect the light from its hinder ſurface, until that ſurface is inclined in an angle of 41 degrees. The diamond therefore will not only throw back all the light which an artificial gem would reflect, but likewiſe one half as much more; which, falling between the angles of 41 deg. and $24\frac{1}{4}$, would have been ſuffered to paſs through by the falſe gem. It is not ſurpriſing therefore that the effect of the diamond ſhould be ſo much greater; more eſpecially, when we attend to its extreme tranſparency, and the accuracy of its poliſh.

— ſoluble in vitriolic acid:

No ſolvent but the vitriolic acid has any effect on this gem; in which, if diamond powder be triturated, and evaporation carried on nearly to dryneſs, the acid grows black, and depoſits pellicles that burn,

— combuſtible.

and are entirely conſumed. In a heat ſomewhat greater than is required to melt ſilver, the diamond is entirely volatilized, and conſumed with a ſlight

that any ſum exceeding one hundred and fifty thouſand pounds has been given for a diamond.

See Magellan's improved edition of Cronſtedt's Mineralogy, for a conſiderable maſs of entertaining information on this ſubject.

DIAMOND.

flame; diminiſhing common air, and leaving a ſoot behind.

Coloured diamonds.

Diamonds are of all colours: the clear tranſparent ſtones are the moſt eſteemed; and, next to them, thoſe of a deeper tinge. Whether theſe coloured ſtones be really of the ſame nature as the clear diamond, has not been aſcertained. The lapidaries reckon them to be diamonds from their hardneſs and luſtre.

BOOK II.

PARTICULAR CHEMISTRY.

SECTION V.

CONCERNING THE PRODUCTS OF THE VEGETABLE KINGDOM.

CHAP. I.

OF THE STRUCTURE AND COMPONENT PARTS OF ORGANIZED SUBSTANCES.

ORGANIZED SUBSTANCES. General observations.

A VARIETY of changes takes place among the great maſs of minerals which come under our obſervation near the ſurface of the earth. Theſe, conſidered individually, appear to be effected chiefly by virtue of the chemical attractions or affinities, aſſiſted by thoſe variations of poſition and of temperature which ariſe from external cauſes; ſuch as the ſolar light, or the alterations which the capacities of other bodies undergo. But in vegetables and animals there

ORGANIZED SUBSTANCES.

The parts of organized bodies conftitute apparatus for performing chemical operations.

is an exprefs organization of parts, which evidently appears to have been defigned by the Supreme Intelligence for the purpofe of uniting the powers of mechanifm to thofe of chemiftry. It does not immediately coincide with our prefent intention, to take any notice of fuch effects as are produced by the mufcular exertion of animals, or any part of their ftructure, except fo far as they modify the chemical proceffes carried on within them. In this point of view, we may confider the folid or confiftent parts of vegetables and animals as compofing an apparatus for performing a number of chemical proceffes with the fluids that circulate through them. It is true indeed that this whole feries of operations is, for the moft part, performed with fuch a minute fet of veffels; at the fame time that the bodies applied to each other, to exercife their refpective chemical attractions, feem in general to be reduced fo near their firft principles; that in the prefent ftate of our knowledge we can fcarcely proceed farther than to affert, that the effects are really produced by an application of the moft fublime chemiftry: but thefe difficulties ought rather to encourage than deprefs our attempts to arrive at a more intimate knowledge of the powers of nature.

Vegetable bodies.

The organs of vegetables appear to confift chiefly of tubes, adapted to imbibe fluid matter from the earth. This fluid, which is moftly water, rifes either by the capillary attraction, by the alternate expanfions and contractions which depend on temperature, or by other means; and depofits its impregnations during its tranfition through the veffels of the plant. The

ORGANIZED SUBSTANCES.

Vegetable bodies.

The action of the folar light, the agitation produced by winds, and the nature of the circumambient air, are of great importance in thefe proceffes. It is known that vegetables do not thrive in vital air; that they abforb fixed air; and that they emit vital air during the action of light, more efpecially the ftrong light of the fun. That they emit plentiful exhalations of various kinds, is obvious from their fmell; from the humidity of countries abounding with woods; as well as from the confideration of the fhort time that would be required to dry the leaves of vegetables, if they did not conftantly receive a fupply of moifture to recruit what they muft lofe by conftant evaporation. We fee therefore that plants are affemblages of veffels, in which water and aërial fluids are received; and by fucceffive mixtures, filtrations, evaporations, or depofitions, are either decompofed, or form new compounds. Thus it may arife from the decompofition of water itfelf, that they emit vital air; while the other principle, or inflammable air, is retained, and enters into the compofition of their combuftible parts. Or, if the decompofition of water be denied, the vital air may arife from the abforption of fixed air; whofe combuftible principle (whether it be fuppofed to be inflammable air, as fome philofophers infer; or charcoal, according to others) may be retained, and anfwer a like purpofe; fince both thefe fubftances are obtained in the inflammation of vegetables.

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Animal bodies.

Animal bodies are of a much more elaborate ftructure. In thefe there is a provifion for mechanically dividing folid bodies by maftication, which anfwers the

ORGANIZED SUBSTANCES. Animal bodies.

the fame purpofe as grinding, pounding, or leviga-tion, does in our experiments; namely, that of en-larging the quantity of furface to be acted upon by folvents. The procefs carried on in the ftomach appears to be of the fame kind as that which we diftinguifh by the name of digeftion; and the bowels, whatever other ufes they may ferve, evidently form an apparatus for filtering, or conveying off, the fluids; while the more folid parts of the aliments, which are probably of fuch a nature as not to be rendered fluid but by an alteration which would perhaps deftroy the texture of the machine itfelf, are rejected as ufe-lefs. When this filtered fluid paffes into the circu-latory veffels, through which it is driven with confi-derable velocity by the mechanical action of the heart, it is not only fubjected to all thofe changes which the chemical action of its parts is capable of pro-ducing, but is likewife expofed to the air of the atmofphere in the lungs, into which that elaftic fluid is repeatedly admitted by the act of refpiration. Here it undergoes a change of the fame nature as happens to other combuftible bodies when they combine with its vital part. This vital part becomes condenfed, and combines with fome principle emitted from the blood; at the fame time that it gives out a large quantity of heat, in confequence of its own capacity for heat being diminifhed. It has not been afcertained whether the fubftance which converts the infpired vital air into fixed air (of which a portion is expired from the lungs together with the noxious or phlogifticated air) be inflammable air or charcoal; and it has likewife been doubted whether any part of the vital air is abforbed

Page 34.
Page 33. 92.
Page 185.

by

by the blood. Later experiments of Dr. Prieſtley ſhew, however, that this laſt event does actually take place *. ORGANIZED SUBSTANCES.

It would lead us too far from our purpoſe, if we were to attempt an explanation of the little we know reſpecting the manner in which the ſecretions, or combinations, that produce the various animal and vegetable ſubſtances, are effected; or the uſes of thoſe ſubſtances in the œconomy of plants and animals. Moſt of them are very different from any of the products of the mineral kingdom. We ſhall therefore only add, that theſe organized beings are ſo contrived, that their exiſtence continues, and all their functions are performed, as long as the veſſels are ſupplied with food, or materials, to occupy the place of ſuch as are carried off by evaporation from the ſurface, or otherwiſe; and as long as no great change is made, either by violence or diſeaſe, in thoſe veſſels, or the fluids they contain. But as ſoon as the entire proceſs is interrupted in any very conſiderable degree, the chemical arrangements become altered; the temperature in land animals is changed; the minute veſſels are acted upon, and deſtroyed; life ceaſes; and the admirable ſtructure being no longer ſufficiently perfect, loſes its figure, and returns, by new combinations and decompoſitions, to the general maſs of unorganized matter, with a rapidity which is uſually greater, the more elaborate its conſtruction.

Secretions, or combinations of vegetable and animal ſubſtances.

Nutrition.

Diſeaſe.

Death.

The parts of vegetable or animal ſubſtances may be obtained, for chemical examination, either by ſim-

* Phil. Tranſ. lxxx. 106.

ple

ORGANIZED SUBSTANCES.

Various methods of feparating the parts of animal or vegetable fubftances.

ple preffure, which empties the veffels of their contents; by digeftion in water, or in other fluids, which diffolve certain parts, and often change their nature; by deftructive diftillation, in which the application of a ftrong heat alters the combination of the parts, and caufes the new products to pafs over into the receiver, in the order of their volatility; by fpontaneous decompofition, or fermentation, wherein the component parts take a new arrangement, and form compounds, which did not, for the moft part, exift in the organized fubftance; or, laftly, the judicious chemift will avail himfelf of all thefe feveral methods fingly, or in combination. He will, according to circumftances, feparate the parts of an animal or vegetable fubftance by preffure, affifted by heat; or by digeftion, or boiling in various fluids added in the retort, which contains the fubftance under examination. He will attend particularly to the products which pafs over; whether they be permanently elaftic, or fubject to condenfation in the temperatures we are able to produce. In fome cafes, he will fuffer the fpontaneous decompofition to precede the application of chemical methods; and in others he will attentively mark the changes which the products of his operations undergo in the courfe of time, whether in clofed veffels, or expofed to the open air. Thus it is that, in furveying the ample field of nature, the philofophical chemift poffeffes numerous means of making difcoveries, if applied with judgment and fagacity; though the progrefs of difcovery, fo far from bringing us nearer the end of our purfuit, appears continually to open new fcenes; and, by en-

larging

larging our powers of inveſtigation, never fails to point out additional objects of enquiry.

Vegetable products arranged.

In treating of the products of the vegetable kingdom, we ſhall attend rather to the proceſſes by which we obtain them, than to any arrangement ſuppoſed to exiſt among their principles. In this way, the order will conſiſt, firſt of principles not ſaline, obtained in a degree of heat not exceeding that of boiling water; ſecondly, ſaline principles, obtained by preſſure, or mere ſolution in water, or ardent ſpirit; thirdly, ſaline principles, obtained by ſtrong heat, or by the action of nitrous acid; fourthly, the products of deſtructive diſtillation; and, laſtly, the products of ſpontaneous decompoſition, or fermentation.

CHAP.

CHAP. II.

CONCERNING SUCH PRINCIPLES OF VEGETABLES AS DO NOT EXHIBIT SALINE PROPERTIES, AND ARE OBTAINED WITHOUT THE APPLICATION OF ANY GREATER HEAT THAN THAT OF BOILING WATER, AND WITHOUT THE ACTION OF ANY SOLVENT BUT WATER, OR ARDENT SPIRIT.

VEGETABLE PRINCIPLES.

Juices and extracts.

THOSE immediate principles of vegetables, which do not evidently exhibit ſaline properties, are called juices, when they flow out of inciſions made in the living plant, or are obtained by ſimple preſſure; and extracts, when rendered thick by evaporation of part of the water they contain. The juices of plants are purified by ſuffering their groſſer parts to ſubſide, or by filtration. In ſome caſes, the fluid is rendered clearer by ſimply heating it in a water-bath, which cauſes part to take the form of a coagulum.

Purification.

Manipulation.

Dry plants, or woods, or ſeeds, are either raſped, pounded, or ground, to ſeparate their parts, and may be macerated, boiled, or digeſted in water, or ſpirit of wine; or the inſoluble parts may be ſubjected to preſſure, to force out their fluid contents. Theſe fluids may be purified by means ſimilar to thoſe which are applied to the expreſſed juices of plants.

The

VEGETABLE PRINCIPLES.

Enumeration of ſuch principles of vegetables as are not ſaline.

The principles of plants which are not of a ſaline nature, and are obtained without deſtroying them by heat, are—1. Gum, or mucilage, which is ſoluble in water, but not in ardent ſpirit. 2. Sugar, which is ſoluble both in water and in ardent ſpirit. 3. Starch, which, though inſoluble in either of theſe fluids, forms a paſte with water, eſpecially if heated. 4. Vegetable gluten, which is neither ſoluble nor diffuſible in water or ardent ſpirit; has a tenacious conſiſtence when recently prepared; but does not imbibe water after it has once been dried. 5. Fat oils, which are inſoluble in water or ardent ſpirit, and are either fluid, or fuſible without alteration, by a moderate heat. 6. Volatile or eſſential oils, which are ſoluble in ardent ſpirit, but not in water, and riſe totally in diſtillation. 7. Camphor, which differs from eſſential oils in being more concrete, more volatile, and in being totally ſoluble, without alteration, in concentrated acids. 8. Reſins, which differ from eſſential oils, in being decompoſable by heat; and from camphor, in being changed by acids. 9. The aromatic principle, or vegetable principle of ſmell. 10. Colouring matters.

Juices or extracts.

The juices or extracts of plants, in general, contain both gum and reſin, which may be ſeparated by their reſpective ſolvents, water and ardent ſpirit. Theſe appear to exiſt together in the plant, forming a compound of a ſoapy or ſaponaceous nature.

Gum.

Gum is a ſubſtance very well known. It is uſually tranſparent, more or leſs brittle when dry, and gives a thick, viſcid, and glewy conſiſtence to water in which it is diſſolved. Gum is uſually obtained by wounding

VEGETABLE PRINCIPLES.

Mucilage or gum.

the trunks or branches of trees, ſuch as the plum, the pear, the cherry tree, &c.; and is diſtinguiſhed by various denominations, according to the plant from which it is obtained. It is obſervable that ſaccharine fruits, when ſour and unripe, are found to contain gum, and an acid; whence the ſaccharine matter ſeems to be formed of theſe principles. This is rendered much more probable from the conſideration that gum and ſugar afford nearly the ſame products by heat, or by diſtillation with the nitrous acid, as we ſhall hereafter ſhew.

Sugar.

Sugar may be reckoned among mucilages or gums: it appears to be brought nearer to the ſaline ſtate. Ardent ſpirit diſſolves it as well as water. The peculiar taſte of this ſubſtance indicates its preſence in a number of fruits and other vegetables; but it is moſt plentifully obtained from the ſugar cane, which is cultivated in warm climates. The juice of the plant is expreſſed by paſſing it between two cylinders of iron, placed perpendicularly. This fluid, which is thick and tenacious, is boiled together with lime and alum, and is afterwards ſuffered to cryſtallize by ſtanding in a veſſel, in the bottom of which are holes imperfectly ſtopped, in order that the ſyrup may drain off. The proceſs of refining ſugar appears to be capable of conſiderable improvement. It is not clearly aſcertained what effect the lime and alum have upon the proceſs; but it is highly probable that a part of the ſugar is burned in the boiling, and converted into an acid, which combines with the lime, and would elſe impede the cryſtallization of the ſugar. The coarſe ſugar thus produced, is refined by ſubſequent ſolution in water, and boiling with a ſmall proportion of lime, together

Manufacture of ſugar.

with

with bullock's blood or eggs. Thefe fluids, which are at firft diffufed through the liquor, have the property of becoming concrete, as the temperature increafes, and rife in the form of fkum to the furface of the fluid, carrying with them the impurities, and rendering it more clear and tranfparent. The filtered liquor is then either poured into moulds, in which, by a confufed cryftallization, it forms loaf fugar; or elfe it is expofed in heated rooms, where, by a gradual cryftallization, it forms fugar-candy.

Manufacture of fugar.

The habitude of fugar with water greatly refembles that of falts; but it has not been afcertained that it contains any falt ready formed, except a fmall proportion of alkali. It is more inflammable than gums.

Flour, or the powder of farinaceous feeds.

Flour, or the pulverized fubftance of farinaceous feeds, has a ftrong analogy to the gummy and faccharine mucilages. Thefe feeds, if moiftened, and expofed to a moderate or fummer temperature, become in a great meafure converted into faccharine mucilages, as happens in the procefs of converting barley into malt.

Wheat flour wafhed in water.

Wheat flour may be taken as an example of the compofition of thefe feeds, before they begin to vegetate frefh. If this be made into a pafte, and wafhed in a large quantity of water, it is feparated into three diftinct fubftances; a mucilaginous faccharine matter, which is really diffolved in the liquor, and may be feparated from it by evaporation; ftarch, which is fufpended in the fluid, and fubfides to the bottom by repofe; and gluten, which remains in the hand, and is tenacious, very ductile, fomewhat elaftic, and of a brown grey colour. The firft of thefe fubftances does not effentially differ from other faccharine muci-

 lages.

VEGETABLE PRINCIPLES.

Starch.

lages. The fecond, namely the ftarch, forms a glewy fluid by boiling in water, though it is fcarcely, if at all, acted upon by that fluid, when cold. Its habitudes and products with the fire, or with nitrous acid, are nearly the fame as thofe of gum, and of fugar. It appears to be as much more remote from the faline ftate than gum, as gum is more remote from that ftate than fugar.

Vegetable gluten.

The vegetable gluten, though it exifted before the wafhing in the pulverulent form, and has acquired its tenacity and adhefive qualities from the water it imbibed, is neverthelefs totally infoluble in that fluid. It has fcarcely any tafte. When dry it is femi-tranfparent, and refembles glue in its colour and appearance. If it be drawn out thin, when firft obtained, it may be dried by expofure to the air; but, if it be expofed to warmth and moifture while wet, it putrefies like an animal fubftance. The dried gluten, applied to the flame of a candle, crackles, fwells, and burns, exactly like a feather or piece of horn. It affords the fame products by deftructive diftillation as animal matters do; is not foluble in ardent fpirit, oils, or ether; and is acted upon by acids and alkalis, when heated.

Fat oils.

Fat oils are obtained by preffure from the emulfive feeds or kernels of vegetables: they are generally fluid in the temperature of the atmofphere, but fome of them have a confiderable degree of firmnefs or folidity. They have a very fmooth feel; are moftly without fmell or tafte; require a degree of heat much fuperior to that of boiling water, to caufe them to rife in ebullition; and cannot be fet on fire, unlefs heated to this degree.

VEGETABLE PRINCIPLES.

Fat oils:

degree. The ufe of the wick of a lamp confifts in bringing fmall portions of oil to its extremity, by the capillary attraction, where they become fucceffively volatilized and inflamed. Oils are remarkably lefs fonorous than water, when poured out. Fat oils, not being at all diffipated by the heat of the atmofphere, make a permanent greafy fpot when they fall on porous fubftances.

— decompofed by diftillation;

Thefe oils are decompofed by diftillation, and afford a fmall quantity of water loaded with a peculiar acid, a light oil, a denfe oil, inflammable air, and fixed air. The refidue confifts of a fmall quantity of charcoal.

— habitudes with air, water, and various fubftances.

Fat oils, by expofure to the air, become rancid; and exhibit a difengaged acid, which may be wafhed off by water. When they are expofed to the air, in a thin coat upon the furface of water, they become more confiftent, like wax, by abforbing the vital part of the atmofphere; the aërated or dephlogifticated marine acid produces this change more fpeedily. Agitation in water feparates a mucilage from them. They combine with magnefia, and with lime, which convert them into faponaceous compounds. With the pure alkalis they form common foap. They do not unite with the volatile alkali, but by long trituration. Page 120.

The mineral acids unite with fat oils, and form compounds, or imperfect foaps. Fuming nitrous acid caufes them to take fire, as has already been obferved. Page 165. Sulphur is foluble in fat oils, by a digefting heat; and is gradually depofited in part from them, in a cryftalline form, by cooling.

Thefe fulphureous compounds are called balfams of fulphur.

VEGETABLE PRINCIPLES.

Bitumens and amber are ſoluble in fat oils, and form varniſhes.

Volatile or eſſential oils:

Volatile or eſſential oils have uſually a ſtrong aromatic ſmell, are ſufficiently volatile to riſe with the heat of boiling water, and are in general ſoluble in ſpirit of wine. They exiſt in almoſt all fragrant vegetables; and in the various plants they are found either in the wood, the root, the bark, the leaves, the flowers, the fruits, &c. They differ very much in the degree of fluidity they poſſeſs at a common temperature, and their colours are various. They are obtained either by expreſſion, as from the peel of oranges and lemons, or by diſtillation with water. Some eſſential oils, ſuch as thoſe of cinnamon, ſaſſafras, and other foreign plants, ſink to the bottom of the water, with which they come over; others float at the top. It is eaſy to diſtinguiſh the adulteration of volatile oils, either by pouring ardent ſpirit upon them, which will not diſſolve the fat oil they may be contaminated with; or if they be dropped on paper, and held to the fire, in this caſe they leave a greaſy ſpot behind. If oil of turpentine be fraudulently added to them, its ſmell betrays its preſence when treated in this manner.

— obtained by preſſure or by diſtillation:

Volatile oils are very inflammable. By expoſure to air, they become thick in proceſs of time, and aſſume the character of reſins.

— are inflammable.

Combinations.

They unite with difficulty to lime and alkalis. The vitriolic acid converts them into bitumens; but, if diluted, it renders them ſaponaceous, as does likewiſe the muriatic acid. Nitrous acid inflames them.

They unite very readily with ſulphur, and form balſams.

fams. Mucilages and fugar render them foluble or diffufible in water.

VEGETABLE PRINCIPLES.

Camphor.

Camphor is a peculiar vegetable fubftance, which refembles volatile oil, and is in fact depofited from fome of the volatile oils by long ftanding. It has been obtained in fmall quantities by diftillation with water from thyme, rofemary, fage, and other fragrant plants. The camphor of commerce is obtained from a fpecies of laurel, which grows in China and the Indian iflands, by diftillation of the wood and other parts of the tree with water. The camphor rifes by the heat, and is afterwards purified by a repetition of the procefs, with the addition of about one-twelfth of its weight of lime.

Characters of camphor:

This fubftance is much more volatile than effential oils. It cannot be preferved without lofs, but in clofed veffels, and even in thefe it fublimes by the heat of fummer. Water does not diffolve it; but it is plentifully foluble in fpirit of wine, in ether, and in concentrated acids; from all which it is feparated, without alteration, by the addition of water. Fixed and volatile oils diffolve camphor, with the affiftance of heat, and depofit cryftals in the form of a beautiful vegetation by cooling.

— its acid.

A peculiar acid is formed by diftillation of the nitrous acid from this fubftance.

Refins, how obtained.

Refins are dried juices of plants, which are of the nature of effential oil. They ufually flow from wounds made in the trunks of trees for that purpofe. Fragrant refins have been diftinguifhed by the name of balfams. Almoft all the concrete juices, diftinguifhed by the name of refins, are foluble in ardent fpirit. Water

 diffolves

VEGETABLE PRINCIPLES.

diſſolves none of them. They are inflammable, and burn with much ſmoke. In cloſed veſſels they do not riſe wholly by heat, like eſſential oils, but are decompoſed.

Reſinous ſubſtances.

A very conſiderable number of reſinous ſubſtances are known and uſed in the arts. Common reſin of the pine, the reſin of the fir, pitch, tar, and turpentine, are among thoſe which are ſoluble in ſpirit of wine, and are of the nature of eſſential oils. Copal, and the elaſtic ſubſtance called caoutchouc, which is the inſpiſſated juice of a tree from Africa, are uſually reckoned among reſins; though neither ſpirit of wine nor water diſſolves them. They are ſoluble however in oils, by the aſſiſtance of heat, and ſeem to be of the nature of fat oils. The juices called gum reſins are variouſly ſoluble in the different menſtruums, according to the nature and abundance of their component parts.

Principle of ſmell in vegetables.

The principle of ſmell in plants appears to be of an exceedingly ſubtile nature. It ſeems in general to reſide in the eſſential oil, and compoſes an extremely ſmall part of the weight of vegetables, as may be inferred from the loſs of fragrance ſuſtained by eſſential oils, with little or no loſs of their weight. This however does not neceſſarily ſuppoſe that the whole principle of ſmell has flown off; becauſe it may with equal probability be ſuppoſed to have entered into combination with ſome of the other principles of the ſubſtance which afforded it. Diſtillation with ſpirit of wine is uſed to extract the fragrant principle from plants. A conſiderable proportion of this matter may be obtained by diſtillation with water, in which it comes over probably diffufed with a fmall proportion of effential oil. It has been fuppofed to confift of an elaftic fluid of a peculiar nature.

VEGETABLE PRINCIPLES.

Colouring matters:

The knowledge of the colouring matters of vegetables is of great importance to fociety, as the art of dying depends on the application of thefe fubftances. Much however remains to be afcertained concerning them. If the doctrine of Newton were incontrovertibly eftablifhed, that the colours of bodies depend folely upon the magnitude of the integrant particles of bodies, we might affert, without hefitation, that all the principles of bodies might be applied in theory to the production of any affignable colour; and we might thence infer, that the colour of plants is not produced by the diffufion of coloured particles of any particular kind, but by the configuration of the parts taken in general. But we are not fufficiently advanced in any part of the knowledge of nature, to reafon with fafety, without conftant recurrence to the teft of experiment. In this way we find that the chemical folvents, in many inftances, deprive plants of their colour, at the fame time that they themfelves acquire it; doubtlefs by folution of the colouring matter, which they again depofit upon bodies prepared for that purpofe. Water diffolves the colouring matter of various fubftances, fuch as logwood, madder, &c. The ftuffs to be dyed require, in many cafes, the previous foaking in a folution of alum, vegetable alkali, or other falts, to prevent their giving the colour out again to water. Other colouring principles are foluble in oils, fuch as alkanet; and many which are not foluble

— are taken up by chemical folvents.

VEGETABLE PRINCIPLES.

Art of dying.

ſoluble in water, are taken up by that fluid, by the intervention of an alkali. The art of dying, or of fixing colouring matter upon various ſtuffs, appears to depend upon the chemical affinities of the colouring matters either with the ſtuffs themſelves, or the matters in which they are previouſly infuſed. The condition required in a good dye appears to be, that the colouring matter ſhall be precipitated on the ſtuff, and form a compound not ſoluble in the liquids to which the ſtuff will probably be expoſed. Thus, for example, printed or dyed linens or cottons ought to reſiſt the action of ſoap and alkalis; and woollens ought more particularly to withſtand the action of acids, ſuch as lemons, vinegar, &c. which may accidentally fall on them.

Lakes.

Certain colours, called lakes, are prepared by diſſolving the vegetable colouring matters, and precipitating them by the addition of ſome other ſubſtance. Thus, for example, if madder be boiled in water together with an alkali, and alum be then added, the earth of the alum will be precipitated together with the colouring matter, with which it will form an inſoluble pigment.

CHAP.

CHAP. III.

CONCERNING THE SALINE PRINCIPLES OF PLANTS OBTAINED BY PRESSURE, OR BY THE APPLICATION OF WATER OR ARDENT SPIRIT; PARTICULARLY THE ACIDS OF LEMONS, OF APPLES, OF NUT-GALLS, AND OF BENZOIN.

VEGETABLE SALTS.

Mineral falts found in vegetables.

THE faline principles of plants are either fuch as are found in the mineral kingdom; namely, vitriolated tartar, Glauber's falt, nitre, common falt, and the fixed alkalis; or they are fuch as are peculiar to this kingdom. The mineral falts are fuppofed to have entered into the veffels of the plants which afford them, and to have remained there unaltered. The falts peculiar to vegetables are, for the moft part, of an acid nature. They confift of the acids of lemons and of apples, which are obtained in an impure ftate by preffure; the acid of nut-galls, and the acid of benzoin; the falts of tartar and of forrel, which contain a portion of alkali; and fuch acids as are formed by diftilling the nitrous acid from vegetable fubftances, which are thofe of fugar, camphor, cork, &c. Deftructive diftillation likewife developes or forms peculiar acids. Thofe obtained from tartar, from mucilage or fugar, and from wood, have only been examined.

Peculiar falts enumerated.

The

VEGETABLE ACIDS.

Various methods of preserving lemon-juice:

The juice of lemons, or limes, has all the characters of an acid of confiderable ftrength. On account of the mucilaginous matter with which it is mixed in its firft ftate, it is very foon altered by fpontaneous decompofition. Various methods have been contrived to prevent this effect from taking place, in order that this wholefome and agreeable acid might be preferved for ufe in long voyages, or other domeftic occafions.

— by oil:

The juice may be kept in bottles under a thin ftratum of oil, which indeed prevents, or greatly retards, its total decompofition; though the original frefh tafte foon gives place to one which is much lefs grateful.

— by evaporation:

In the Eaft Indies it is evaporated to the confiftence of a thick extract. If this operation be carefully performed by a very gentle heat, it is found to be very effectual. When the juice is thus heated, the mucilage thickens, and feparates in the form of flocks; part of which fubfides, and part rifes to the furface: thefe muft be taken out. The vapours which arife are not acid. If the evaporation be not carried fo far as to deprive the liquid of its fluidity, it may be long preferved in well-clofed bottles; in which, after fome weeks ftanding, a farther portion of mucilage is feparated, without any perceptible change in the acid.

— by freezing.

Of all the methods of preferving lemon juice, that of concentrating it by froft appears to be the beft; though, in the warmer climates, it cannot conveniently be practifed. Lemon juice, expofed to the air in a temperature of between 50° and 60°, depofits in a few hours a white femi-tranfparent mucilaginous matter, which leaves the fluid, after decantation and filtration, much

much lefs alterable than before. This mucilage is not of a gummy nature, but refembles the gluten of wheat in its properties: It is not foluble in water, when dried. More mucilage is feparated from lemon juice by ftanding in clofed veffels. If this depurated lemon juice be expofed to a degree of cold of about feven or eight degrees below the freezing point, the aqueous part will freeze, and the ice may be taken away as it forms; and if the procefs be continued until the ice begins to exhibit figns of acidity, the remaining acid will be found to be reduced to about one-eighth of its original quantity, at the fame time that its acidity will be eight times as intenfe; as is proved by its requiring eight times the quantity of alkali to faturate an equal portion of it. This concentrated acid may be kept for ufe; or, if preferred, it may be made into a dry lemonade, by adding fix times its weight of fine loaf fugar in powder *.

Depuration of the acid of lemons:

—by congelation:

The above proceffes may be ufed when the acid of lemons is wanted for domeftic purpofes; becaufe they leave it in poffeffion of the oils, or other principles, on which its flavour peculiarly depends. But in chemical refearches, where the acid itfelf is required to be had in the utmoft purity, a more elaborate procefs muft be ufed. Boiling lemon juice is to be faturated with powdered chalk, whofe weight is to be noted. The neutral faline compound is fcarcely more foluble in water than felenite: it therefore falls to the bottom; while the mucilage remains fufpended, in

—by the chemical affinities.

* Georgius, quoted by Fourcroy, iv. 33.

the

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Depuration of acid of lemons.

the watery fluid which muſt be decanted off. The remaining precipitate muſt then be waſhed with warm water until it comes off clear. To the powder, thus edulcorated, a quantity of vitriolic acid, ſufficient to ſaturate the chalk, and diluted with ten parts of water, muſt be added, and the mixture boiled a few minutes. The vitriolic acid combines with the lime, and forms ſelenite, which remains behind when the cold liquor is filtered; while the diſengaged acid of lemons remains diſſolved in the fluid. This laſt muſt be evaporated to the conſiſtence of a thin ſyrup; and vitriolic acid muſt be then added in ſmall portions, to precipitate the lime, if any ſhould ſtill remain in combination with acid of lemons. When no more precipitate is afforded by the addition of vitriolic acid, a farther evaporation ſeparates the pure acid of lemons in cryſtals. It is neceſſary that the vitriolic acid laſt added ſhould be rather in exceſs; becauſe the preſence of a ſmall quantity of lime will prevent the cryſtallization. This exceſs will be found in the mother water *.

Characters.

The concrete acid of lemons remains conſiſtent in the air, is very ſoluble in water, and exhibits ſtrong acid properties. Its watery ſolution is decompoſed by a ſlow putrefaction. It unites with the alkalis and earths, ſilex excepted; and forms peculiar neutral ſalts, which have not yet been much examined. Several of the metallic ſubſtances are likewiſe acted upon by it; and it would probably diſſolve all their calces.

* Scheele's Eſſays, Eng. Tranſlation, p. 361; or Crell's Journal for 1784.

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Method of purifying the acid of apples.

The acid which abounds in four or unripe fruits exhibits diftinct properties. As it is plentifully obtained from apples, the firft examiner, Scheele, has denominated it the acid of apples. In order to obtain it, the juice of four apples is expreffed from the fruit, and faturated with vegetable alkali. To this liquor a folution of the vitriolic falt of lead muft be very gradually added. A double decompofition takes place. The vitriolic acid combines with the alkali, and forms vitriolated tartar; at the fame time that the acid of apples, uniting with the lead, forms an infoluble precipitate. When the precipitate nearly ceafes to fall down, the folution of fugar of lead muft be added cautioufly, by a drop at a time, until no more precipitate is afforded. The vitriolated tartar may be wafhed off from the precipitate; and diluted vitriolic acid being then poured on the precipitate, fugar of lead is again formed, and the acid of apples is fet at liberty.

Separation of the acids of lemons and of apples.

In fuch fruits as contain the acid of lemons as well as that of apples, the feparation of one from the other is accomplifhed by the following procefs. The juice of goofeberries, for example, is evaporated to the confiftence of fyrup: pure ardent fpirit being poured upon this, diffolves the acids, and leaves the mucilage, which may be feparated by filtration. The ardent fpirit being then evaporated, and water added, the acids muft be faturated with chalk. The folution being boiled for a few minutes, the calcareous falt of lemons falls to the bottom, on account of its difficult folubility; while the other falt, confifting of the acid of apples, united to lime, remains fufpended, and may

confe-

VEGETABLE ACIDS.

consequently be decanted off. This neutral salt not being soluble in spirit of wine, may be precipitated by the addition of a proper quantity of that fluid; which, at the same time, deprives it of a portion of saponaceous and saccharine matter. The coagulum, or precipitate, which consists for the most part of the acid of apples, perfectly neutralized by lime, may be dissolved in boiling water. An addition of sugar of lead forms a precipitate by double affinity, as in the first case, consisting of the acid of apples united to lead; and this washed precipitate may be decomposed by the addition of diluted vitriolic acid, which combines with the lead, and sets the acid of apples at liberty.

Acid of apples.

Characters.

This acid exhibits peculiar properties. It cannot be obtained in crystals; and forms deliquescent salts with the three alkalis, and also with magnesia. Its saline combination with lime is crystallizable; and with clay it forms a salt of very sparing solubility. It dissolves iron, with which it forms a salt that does not crystallize. With zinc, it forms a salt which affords beautiful crystals. It precipitates the nitrous solutions of mercury, lead, silver, and gold, in the metallic state: when nitrous acid is distilled from it, it is converted into acid of sugar.

The astringent principle.

Many vegetable substances, such as the husks of nuts, the bark of the oak, the nut-gall, and other vegetable matters, abound with a substance which has been distinguished by the name of the astringent principle. Its distinguishing character is that of precipitating iron from its solutions in acids, of a black colour. The nut-gall is chiefly used for this, and other

purposes

purpofes wherein the application of this property is required; and, as it refembles acids in its properties, the principle has been called the acid of galls.

VEGETABLE ACIDS.

Acid of galls obtained in folution:

The acid of galls is obtained by macerating the nut-gall in water. This infufion reddens turnfole and blue paper. The acid is foluble in oils, ardent fpirit, and ether. Acids diffolve it, without impairing its property of forming a black precipitate with the folutions of iron: the diftilled products of nut-galls likewife poffefs the fame property. It decompofes metallic folutions, and combines with their calces: gold and filver are precipitated by it in the metallic ftate. It acts upon and diffolves iron directly.

—in the cryftallized form.

To obtain the acid of nut-galls in a cryftallized form, one pound of the powder of galls muft be added to fix pounds of diftilled water, and left to digeft for a fortnight, at the temperature of between 70 and 80 degrees; after which, the fluid muft be filtered, and left to evaporate fpontaneoufly in the open air, in a ftone-ware or glafs veffel. The fluid becomes mouldy, and covered with a thick glutinous pellicle; abundance of glutinous flocks fall down; and in the courfe of two or three months the fides of the veffel appear covered with fmall yellowifh cryftals, which are likewife very abundant at the under furface of the pellicle which covers the liquor. The fluid muft then be decanted; and ardent fpirit, being poured upon the mucilaginous depofition, the cryftals and the pellicle, diffolves the falt by the affiftance of heat, without touching the mucilage; and, by evaporation of this fpirituous folution, the pure gallic acid is obtained in fmall brilliant cryftals, of a grey colour inclining to yellow.

VEGETABLE ACIDS.

Page 300. General characters and habitudes of the acid of galls.

This acid, on account of its long expofure to the air, may confift either of a principle exifting in the galls, or of that principle converted into an acid. It has the following properties: It precipitates martial vitriol, and other falts of iron, of a beautiful black colour, and ftrongly reddens the tincture of turnfole: when heated, with contact of air, it fwells up, and burns, leaving a coal behind of difficult incineration: by diftillation, with a gentle heat, part of the acid comes over diffolved in the water of cryftallization: another portion fublimes undecompofed in the form of filky cryftals; and a ftrong heat feparates a few drops of oil, with fixed and inflammable air.

The acid of galls is foluble in twenty-four parts of cold water, or three of boiling water. It is much more foluble in fpirit of wine; four parts of this being fufficient at the common temperature, or one when boiling hot. With lime, magnefia, or ponderous earth, it forms falts which are foluble in water: it unites readily with the alkalis, and forms compounds, which have not been much attended to. The action of the nitrous acid converts it into the acid of fugar. This acid precipitates gold, filver, mercury, copper, iron, and bifmuth, from their folutions; but it does not affect thofe of platina, zinc, tin, cobalt, and manganefe.

Benzoin.

The fragrant refin, called benzoin, affords a peculiar concrete acid by fublimation, which is about one tenth of the weight of the refin itfelf, but varies in different fpecimens. This acid exifts ready formed in the benzoin; but cannot eafily be wafhed out by water,

VEGETABLE ACIDS.

water, on account of the resin which defends it. The best method of obtaining it, in the humid way, is the following: Lime-water is made by slacking four ounces of quick-lime with twelve ounces of water; and, as soon as the ebullition is over, eight pounds more of water are to be added. Six ounces of this lime-water are to be mixed by agitation with one pound of benzoin in powder, and the whole of the lime-water is then to be added; the mixture being exposed to heat over a gentle fire for half an hour (during which time it must be continually agitated, to prevent the powder from coagulating), is afterwards suffered to cool, and settle for several hours. The clear liquor must then be decanted, and the residue boiled for half an hour with eight pounds of water; which, after subsidence and decantation, must be added to the clear fluid of the first boiling. The ebullition of the residue of the matter must be again twice repeated, and the decanted lixiviums added to the foregoing. All these waters are then to be evaporated to two pounds; during which operation a small quantity of resin falls down. When the evaporated liquor is cool, a quantity of marine acid must be added drop by drop, with constant stirring, till there be no more precipitation, or till the mass has a sourish taste. The precipitate is the acid of benzoin.

Method of obtaining the acid of benzoin in the humid way.

The rationale of the above process is this: The lime unites with the acid of benzoin during the ebullition: the evaporation separates a small quantity of resin; and diminishes the aqueous fluid so much, that in the subsequent part of the operation the acid of benzoin may fall down, and be separated for want of

Rationale.

VEGETABLE ACIDS.

Method of obtaining the acid of benzoin.

a ſufficient quantity of water to diſſolve it. The marine acid, which is added laſt of all, ſeizes the lime by its ſtronger affinity, and forms a ſoluble ſalt; while the acid of benzoin, which is diſengaged, falls down, on account of its ſparing ſolubility. The acid thus obtained has the form of a very fine powder. If it be required in the form of ſilky threads, it may be diſſolved in boiling water, and ſtrained through a cloth. As cold water diſſolves little more than one five hundredth part of its weight, though boiling water diſſolves about one twentieth of this acid, the greateſt part of the acid ſeparates by cooling.

Its characters.

The acid of benzoin combines with the ſoluble earths and alkalis, and forms compounds, which have been little attended to. It is ſoluble in the vitriolic and nitrous acids; and may be again ſeparated, without alteration, by the addition of water. Its habitudes with theſe acids, particularly the latter, when heated, have not been ſatisfactorily aſcertained. If its nature be changed by diſtillation with nitrous acid, it ſeems probable that it is effected with much more difficulty than is experienced with other vegetable acids.

CHAP.

CHAP. IV.

CONCERNING THE ACIDS OF TARTAR AND OF SORREL.

VEGETABLE ACIDS.

Tartar.

THE two acids which are usually found in combination with a portion of the vegetable alkali, are the acid of tartar and of wood sorrel. Tartar has for a long time been considered as one of the products of the vinous fermentation; but it exists ready formed in must, in verjuice, and is likewise obtained in other chemical processes with vegetables. However, it is obtained, for all the purposes of commerce, from wine; during the insensible fermentation of which liquid, it is gradually deposited on the sides of the casks.

Cream and crystals of tartar.

Crude tartar is seldom used in medicine, or philosophical chemistry; the refined tartar is known by the name of cream, or crystals, of tartar. The purification of this salt is effected by dissolving it in boiling water, filtering and suffering it to crystallize by cooling; the crystals are again boiled, together with an argillaceous earth, to deprive them of their impurities, which are carefully scummed off; or else with whites of eggs, which answer the same purpose. When no more scum arises, a saline pellicle is formed at the top of the liquor, at the same time that the crystallization goes forward at the bottom. This salt, after the earth is washed off with cold water, is sold under the name

 of

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of cream, and cryftals of tartar. The cream of tartar confifts of the minute cryftals which are formed at the top of the liquor, and the cryftals of tartar are formed at the bottom.

Characters of purified tartar.

The tafte of this purified falt is lefs vinous than that of the crude tartar. When expofed to heat, it boils up, emits an epyreumatic fmell, and becomes black and coaly; a ftronger heat in an open fire entirely diffipates its acid part, and leaves the vegetable alkali in a mild ftate, or combined with fixed air. Its volatile products, by a gradual fire, are water, an acid, and an epyreumatic oil, which is followed by fome volatile alkali, and a large quantity of fixed air. Cryftals of tartar are foluble in twenty-eight parts of boiling water; three-fourths of the falt are depofited in cooling. If the folution of this falt be left expofed to the air, it is very flowly decompofed; mucilage is depofited, the acid difappears, and after eighteen months the liquid is found to contain the vegetable alkali, amounting to nearly one-fourth of the weight of the tartar. This quantity of alkali being nearly the fame as is afforded by the incineration of tartar, is a proof that the vegetable alkali is not a product of fire, as was formerly fuppofed.

Habitudes.

The habitudes of tartar with clay and ponderous earth have not been afcertained. Magnefia forms with it a foluble falt. Chalk unites with the excefs of acid in the tartar, and feparates the neutral falt; confifting of the vegetable alkali, faturated with the tartareous acid, which is known by the name of foluble tartar.

Soluble tartar.

If the vegetable alkali be added to a folution of cream of tartar, in fuch a quantity as to faturate it, the fame neutral

neutral salt, or soluble tartar, will be formed. This has a bitter taste, and is decomposed by heat, affording the same volatile products as cream of tartar. It is soluble in four parts of water heated to 110°, and affords crystals which are slightly deliquescent.

Soluble tartar.

It is a curious fact, though by no means singular in the history of neutral salts, that two very soluble substances, such as the vegetable alkali, and the acid of tartar, should compose a salt of so little solubility as the crystals of tartar; more especially, as the point of the greatest difficulty of solution is not that at which they are saturated, but that in which the acid so considerably abounds.

Curious fact.

If to twenty ounces of purified tartar, dissolved in four pounds of boiling water, the pure crystallized mineral alkali be added, until the saturation be complete, as may be judged by any additional quantity producing no effervescence; the alkali last added will combine with the superfluous acid of the tartar, and form the neutral combination called the salt of Seignette, or Rochelle salt; at the same time that the residue of the tartar will become converted into soluble tartar. By evaporating the liquor nearly to the consistence of syrup, the Rochelle salt is obtained in beautiful regular prisms, of six or eight sides, which effloresce in the air, and are decomposed by heat in the same manner as soluble tartar.

Manufacture of Rochelle salt.

By the same treatment with volatile alkali, an ammoniacal tartareous salt is formed, which affords crystals that effloresce in the air.

If the mineral acids be added to tartar, they combine with its alkali, and form the same salts as they

Ammoniacal salt of tartar.

 would

VEGETABLE ACIDS.

would have produced by direct union with the vegetable alkali.

Tartar.

Tartar has long been an object of attention with chemifts, and it is ufed as an acid in many of the arts. This falt appears to be capable of uniting without decompofition, and forming triple falts with moft of the metals.

Method of obtaining the acid of tartar:

The pure acid of tartar may be obtained by faturating three parts of cream of tartar with chalk or lime; the former of which combines with the fuperfluous acid, and the latter feizes the whole. The calcareous tartar, which, on account of its infolubility, remains at the bottom, is then to be well wafhed, and digefted with about one part of vitriolic acid, together with a fufficient quantity of water. In this manner the acid of tartar is difengaged. The felenite formed by the combination of the vitriolic acid and the lime, will be feparated, and fall down, by evaporating the water; and the acid which remains may be cryftallized by further evaporation and cooling.

— or otherwife.

Or, more fimply, one pound of cream of tartar may be boiled in five or fix pounds of water, and a quarter of a pound of clear and colourlefs denfe vitriolic acid may be added by little and little. When a complete folution is obtained, the fluid will then contain difengaged acid of tartar, together with vitriolated tartar, or the neutral falt, formed by the union of the vitriolic acid with the vegetable alkali. The vitriolated tartar, being a falt of fparing folubility, will be precipitated by continuing the boiling. When the liquor is evaporated to one half, it is to be filtered; and if, upon further evaporation, any thing more is precipitated,

pitated, it muſt be filtered again. The clear liquor being then reduced to the conſiſtence of a ſyrup, and ſet by in a temperate or rather warm place, will afford fine cryſtals of tartareous acid, equal in weight to half the cream of tartar employed. If too ſmall a quantity of vitriolic acid has been uſed, part of the cream of tartar will not be decompoſed, but will ſeparate from the liquor along with the vitriolated tartar. It is better therefore to uſe too little rather than too much.

VEGETABLE ACIDS.

Acid of tartar:

—its characters,

The cryſtallized tartareous acid melts, fumes, becomes black, and burns, by the contact of ignited bodies. By diſtillation it affords an acid phlegm, a ſmall quantity of oil, and much fixed air, together with inflammable air; leaving behind a coaly reſidue, which contains neither acid nor alkali.

and habitudes.

The cryſtals of tartareous acid do not change by expoſure to air; they are much more ſoluble in water than cream of tartar itſelf. This acid diſſolves clay, and forms a ſalt which, by evaporation, aſſumes a clear gummy conſiſtence, and does not deliqueſce in the air. The ſame appearance is exhibited with magneſia: with lime, it forms a ſalt which is ſcarcely at all ſoluble; a due proportion of vegetable alkali converts it into cream of tartar, which falls down if the water of ſolution be not ſufficiently abundant, but is diſſolved again if more alkali be added, ſo as to convert it into ſoluble tartar. Theſe ſynthetical operations ſhew that the tartareous acid is not altered by the proceſs of extracting it from cream of tartar.

With the mineral alkali it forms the Rochelle ſalt, and with volatile alkali it forms a cryſtallizable ſalt.

In

VEGETABLE ACIDS.

In this laſt combination there is a term at which cryſtals of ſparing ſolubility, like thoſe of cream of tartar, are formed; and in this caſe likewiſe the acid of tartar is far from being ſaturated with the alkali.

This acid is convertible into the ſaccharine acid by diſtillation with ſtrong acid of nitre: and it is converted into acetous acid by digeſtion with water and ardent ſpirits.

Salt of ſorrel:

Salt of ſorrel is a cryſtallized ſalt; ſo denominated becauſe it is obtained from the wood ſorrel, or oxalis aceto-ſella of Linnæus, for the purpoſes of commerce; though it may be obtained from ſome other plants. It is in white cryſtals, whoſe figure has not been well determined, on account of their minuteneſs. When it is expoſed to diſtillation in a retort, the acid is partly decompoſed; a conſiderable quantity of acid phlegm comes over, which is without ſmell or colour, and conſiſts of the acid itſelf, ſcarcely altered; and the reſidue affords vegetable alkali, amounting to ſomewhat more than one third of the weight of the ſalt. Expoſure to air does not alter the ſalt of ſorrel. It is very ſparingly ſoluble in cold water: but boiling water may take up one ſixth part, or more, of its weight; the quantity varying according to the ſtate and purity of the ſalt, which ſeems to vary in different ſpecimens.

— characters:

— action upon various ſubſtances.

Salt of ſorrel acts upon various ſubſtances without decompoſition. With ponderous earth, magneſia, vegetable alkali, and volatile alkali, it forms triple ſalts. Lime decompoſes it by ſeizing the whole of the acid, and diſengaging the alkali. The attraction of this acid for lime is ſo ſtrong, that it cannot be diſengaged from

from it by any other acid: another procefs is therefore neceffary to be ufed for obtaining it. With this intention, the fuperabundant acid is to be faturated with volatile alkali; and into this folution muft be poured a folution of ponderous earth in the nitrous acid. The laft-mentioned acid combines with the alkalis, forming nitrous ammoniac, and common nitre, both which remain in folution; while the ponderous earth, combining with the acid of forrel, forms an infoluble compound, which falls to the bottom. This precipitate, after being well wafhed, may be decompofed by the addition of vitriolic acid, which feizes the earth, and likewife forms an infoluble combination, while the acid is fet at liberty. After decantation of the clear liquid, it muft be affayed by pouring into it a little at a time of the boiling hot folution of ponderous earth in the acid of forrel. If there be any excefs of vitriolic acid, a precipitate will be formed by its union with the ponderous earth. A due evaporation and cooling of this liquor afford the acid of forrel, in prifmatic four-fided cryftals or fquare plates.

Method of purifying the acid of forrel.

Characters.

This acid has a confiderable degree of ftrength. Expofed to heat in a retort, it falls into powder, with the lofs of three tenths of its weight, after which it melts, boils up, at the fame time that its colour changes to a brown. An acid phlegm comes over, and part of the acid fublimes without alteration. Fixed air and inflammable air are difengaged during this decompofition of the acid; and their quantity is greater, the more violent the heat.

Combinations.

Boiling water diffolves its own weight of this concrete acid falt, half of which is feparated in cryftals by

Combinations of the acid of sorrel.

by cooling. It diffolves clay, and affords a deliquefcent mafs by evaporation. With ponderous earth it forms a falt fcarcely foluble, except there be an excefs of acid; in which cafe it affords tranfparent cryftals, which become opake, powdery, and infoluble, when the excefs of acid is taken up by boiling water. With magnefia, it forms a white powdery falt; and with lime it forms an infoluble compound, which cannot be decompofed in the moift way, becaufe the affinities of thefe two fubftances are ftronger than any which exift between either of them and other known bodies. From this property, the acid of forrel is ufed as the teft of the prefence of lime, which it precipitates from all its combinations.

Synthefis.

If vegetable alkali be gradually added to a folution of this acid in water, a precipitate falls down, which is the falt of forrel, and contains the acid in excefs. A farther addition of alkali faturates the acid, and forms a very foluble falt, which is capable of cryftallizing, if the alkali be in excefs. With an excefs of the mineral alkali it forms a falt of fparing folubility. With volatile alkali it affords a cryftallizable falt; and with both thefe alkalis, if the acid be in excefs, it forms a lefs foluble falt, fimilar to what happens with the vegetable alkali.

It acts on feveral of the metals directly, but in general combines more readily with their calces.

This acid does not differ from the acid of fugar. Treatment with nitrous acid converts it into acetous acid and fixed air; or totally into the latter, if the action be rapid.

CHAP.

CHAP. V.

CONCERNING THE VEGETABLE ACIDS PRODUCED OR DEVELOPED BY DESTRUCTIVE DISTILLATION, OR BY THE ACTION OF NITROUS ACID.

VEGETABLE ACIDS: ARTIFICIAL.

Confiderations on the compofition and decompofition of vegetable bodies.

IN the courfe of the preceding accounts of the vegetable acids, it may be obferved, that they are all fubject to great alterations by the action of chemical agents; and they are all fubject to fpontaneous decompofition. They feem to obtain their acid properties by the combination of a bafe with the vital part of the air, in the fame manner as has been more fully fhewn with regard to the mineral acids; but they appear to be of too compounded a nature to retain the order or arrangement of their component parts through thofe great varieties of temperature, to which in general the mineral acids may be fubjected. Heat alters the arrangement of their component parts, and feparates them from each other in a new form. The products of all vegetable fubftances including thefe acids are found, when urged by fire, to be water, fixed air, inflammable air, oil, coal, and alkali. If we confider water as decompofable, and confifting of vital and inflammable air; if we confider oil as compofed of fixed air and inflammable air; and again, whether we admit charcoal to confift chiefly of inflammable air, according to the opinion of fome chemifts, or of the

VEGETABLE ACIDS: ARTIFICIAL.

Simplicity and ſmall number of vegetable principles.

the peculiar baſis of fixed air, according to others; and, laſtly, if fixed air be allowed to conſiſt of charcoal united to vital air, whether the charcoal be conceived as a peculiar ſubſtance, or as inflammable air in a ſtate of condenſation; we ſhall at length find that the component parts of vegetables are very few; inſomuch that, if the foregoing poſitions were clearly eſtabliſhed, they would conſiſt either of charcoal, vital air, and inflammable air, or elſe of vital air and inflammable air only. From the various proportions of theſe, in different ſtates of condenſation, it would follow, that water, fixed air, oils, mucilages, and acids, are produced; and that the beautiful variety of nature ariſes from this arrangement and combination.

Empyreumatic acids.

The firſt action of fire upon the vegetable acids does not in general alter their combinations ſo much, but that ſome other acid comes over together with the elaſtic products. Theſe acids, which on account of the peculiar ſmell which they obtain from the fire are called empyreumatic, would probably, on examination, be found to be of various kinds. Thoſe which have hitherto engaged the attention of chemiſts, are the empyreumatic acid of tartar; the empyreumatic acid of ſugar or mucilage, formerly called ſpirit of honey; and the empyreumatic acid of wood, which is ſuppoſed to be the ſame in all woods, and has been diſtinguiſhed by the name of ſpirit of box.

Empyreumatic acid of tartar.

The empyreumatic acid of tartar, is the acid phlegm which comes over when cream of tartar is expoſed to diſtillation. This acid is impure, on account of ſome oil which comes over with it, and from which it can only be ſeparated by the funnel; becauſe it dilates ſo ſuddenly, when an attempt is made to rectify it by a ſecond diſtillation, that it burſts the veſſels. The acid properties of this fluid are ſufficiently apparent, though it does not redden the tincture of violets, as it does turnſole and blue paper. It forms peculiar compounds with the earths and alkalis, which have not been much examined, but are very different from thoſe afforded by the acid of tartar.

Empyreumatic acid of tartar:

When inſipid gummy ſaccharine or farinaceous mucilages are expoſed to diſtillation, an empyreumatic acid comes over, of a reddiſh yellow colour, and a bitter, acrid, and ſour taſte. By rectification with the addition of clay, the acid comes over clear, and leſs empyreumatic. It does not afford cryſtals, but may be concentrated by freezing, which converts its aqueous part into ice. In this ſtate it ſtrongly reddens blue vegetable colours, and forms a red ſpot where it falls on the ſkin. By diſtillation, cautiouſly managed in cloſe veſſels, it may be converted for the moſt part into fixed and inflammable air.

— of ſugar or mucilage:

The empyreumatic acid of ſugar attacks and diſſolves the ſoluble earths and alkalis. It corrodes lead, copper, tin, and iron: but the compounds it forms with theſe bodies have been little attended to.

Box, birch, and other woods, when expoſed to diſtillation, afford that peculiar acid, which is ſo offenſive to the eyes when the ſmoke of a ſmothering wood fire forces itſelf into an apartment. This acid has conſiderable ſtrength. The oil which comes over

— of wood.

with

VEGETABLE ACIDS: ARTIFICIAL.

Acid of wood.

with it, may be ſeparated, either by ſtanding for ſome months, or by rectification. It cannot be obtained in a concrete form. A ſtrong heat decompoſes it. With earthy and alkaline baſes it forms peculiar ſalts, whoſe general properties have not been minutely enquired into. As the properties of the acid obtained from a conſiderable variety of woods have proved to be the ſame, it is preſumed that all woods contain this common acid, or at leaſt that combination of principles which conſtitutes its baſe.

Obſervations on the effect of nitrous acid upon vegetable bodies.

Since the acidification of combuſtible ſubſtances is evidently produced by the application or combination of vital air; and as, in all the operations of chemiſtry, effects may be produced by one mode of combination, which are impracticable in others; it becomes neceſſary, in chemical reſearches, to try every means which can be deviſed. Few vegetable acids are artificially produced by the direct application of vital air to the principles of that claſs of bodies; but many experiments have been made by abſtracting the nitrous acid from vegetables by diſtillation. This acid, as we have frequently had occaſion to obſerve, is very eaſily decompoſed, when applied to combuſtible bodies, which attract its vital air, and diſengage either nitrous or phlogiſticated air, as we have explained in our chapter upon that acid. It has likewiſe been obſerved, in various parts of the preſent ſection, that this acid, when repeatedly diſtilled from gums, mucilages, ſugar, the acids of tartar, of apples, and of gall, produces the peculiar acid which has been called the acid of ſugar; and, if the abſtraction be repeated too often, the acid

Chap. III. IV.

of

VEGETABLE ACIDS: ARTIFICIAL.

The progrefs of acidification in vegetable bodies.

of fugar itfelf is converted into fixed air. From this view of the fubject, together with other facts, it has been inferred, that a greater or lefs proportion of vital air, united with one general principle abundantly exifting in charcoal, whether this principle be inflammable air or not, produces all the various acids of vegetables. Thus tartar, which is the leaft acidified, is faid to become converted into the acid of apples by treatment with nitrous acid. The acid of apples, by a continuance of the operation, becomes converted into acid of fugar, or acid of forrel, which are the fame thing. The fame procefs, further continued, affords vinegar *, which comes over. Hence it fhould feem that, according to the greater progrefs which the operation of combuftion, or the combination of vital air with the bafe (which at the fame time, according to the ancient theory, is fuppofed to be more dephlogifticated), the acids of tartar, of apples or unripe fruit, of forrel or fugar, of vinegar, and laftly, of fixed air, are produced. In this order of proceeding, the acids become more and more perfect, and lefs eafily decompofable: and on this account probably it is, that attempts to reverfe the proceffes have not hitherto been attended with much fuccefs.

Difference between the acids of fugar and forrel.

Since the difcovery that the acid of fugar does not differ from that of forrel but in containing a fmall proportion of alkali, the procuring of the former in the expenfive way of diftillation with nitrous acid, is

* See Scheele's Effays, Englifh tranflation, page 385; and the Journal de Phyfique for January 1788, page 59.

VEGETABLE ACIDS: ARTIFICIAL.

become unneceffary. We fhall, neverthelefs, defcribe the procefs here, as an example of that method of operating.

The procefs for converting fugar into an acid.

Three ounces of ftrong nitrous acid, whofe fpecific gravity was nearly 1.567, were mixed in a tubulated retort with one ounce of the fineft fugar in powder. Much nitrous air efcaped in red fumes, formed by combination with the vital air of the atmofphere. A receiver was then adapted, and the liquor gently boiled. As foon as the mixture had acquired a dark brown colour, three additional ounces of nitrous acid were added, and the boiling was continued until the coloured and fuming acid had entirely difappeared. The liquor being then poured out, afforded fmall prifmatic cryftals by cooling, which are the acid of fugar. The lixivium being again treated in the fame manner, with two ounces of nitrous acid, afforded an additional portion of acid of fugar by cooling; and the remaining glutinous liquor, treated at different times with fmall quantities of nitrous acid, amounting in the whole to two ounces, and evaporated to drynefs, afforded a faline mafs: and, laftly, the whole was depurated by repeated folutions and cryftallizations in water. In this way, with three parts of fugar, and thirty of nitrous acid, the quantity of one part of acid of fugar is obtained.

Obfervation.

The above procefs is taken from Bergmann: but it may be obferved that weak nitrous acid, or common aqua fortis, will anfwer the purpofe as well as the concentrated acid; and that, where it is not an object to collect the acid which comes over, there will be no need of any receiver, or other apparatus, except a

matrafs,

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matrafs, or Florence flafk, to perform the operation in a chimney where there is a proper draught of air to carry off the acid fumes.

Acid of camphor.

The acid of camphor * is produced by diftilling the nitrous acid eight fucceffive times from camphor. It is of a concrete cryftalline form, of a bitter tafte, and reddens the tinctures of violets and turnfole. It differs from the acid of fugar in not feparating lime from the marine acid. With vegetable alkali it forms a falt in regular hexagons; with mineral alkali, a falt in irregular cryftals; with volatile alkali, prifmatic or needle-formed cryftals; and with magnefia, a pulverulent foluble falt. It diffolves feveral metallic fubftances. But fubfequent enquiries are wanting to eftablifh the peculiar nature and properties of this acid.

Acid of cork.

By diftilling four times its weight of nitrous acid from cork, a yellowifh thick acid matter is obtained, which is foluble in water, and has an auftere bitterifh tafte. It does not cryftallize, but becomes confiftent like wax by evaporation; is foluble in ardent fpirit; forms deliquefcent falts with the earths and alkalis; and has as ftrong an attraction for lime as the acid of fugar †.

* Kofegarten, Nouv. de la Republ. des. Lettres, Année 1785. Nos. 42 and 44; quoted by Fourcroy, Elem. Chem. iv. 104, edition of 1789.

† Brugnatelli, in the Journal de Phyfique, Auguft 1787; or Crell's Annals for the fame year.

CHAP. VI.

ON THE DESTRUCTIVE DISTILLATION OF VEGETABLE SUBSTANCES.

VEGETABLE PRODUCTS BY FIRE.

Destructive distillation.

IN the foregoing chapters we have occasionally treated of the decomposition of vegetables by destructive distillation, and have described the volatile products it affords. As the immediate principles of organized substances are for the most part very compounded, and the extreme temperature produced in this method tends to reduce them to their primary component parts, it is evident that very little can be learned in this way concerning that on which the various properties of those substances depend. But as the chemist ought to neglect none of the methods he possesses of producing changes in bodies, this process may have its use when compared with others, and more especially when we shall have arrived at that knowledge of the first principles of organized substances, which from a variety of facts, and the late rapid progress of chemistry, we have reason to hope for. We shall therefore proceed to describe the general phenomena of destructive distillation.

This process consists merely in exposing any organized substance to heat in a retort, placed in a reverberatory furnace. The ancient chemists, who paid no attention to the elastic products, except so far as their

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their expanſive force impeded their operations, uſually drilled a ſmall hole in the upper part of the receiver for their eſcape. Modern chemiſtry proceeds in a more ſcientific manner, by uſing the pneumatic apparatus, fig. 21. The firſt product which comes over in the diſtillation of vegetables, is a watery fluid, containing acid and odorant principles. In proportion as the deſtruction of the vegetable proceeds, the phlegm becomes deeper coloured, and more ſaline. Next follows a coloured oil, which becomes of a darker hue as the diſtillation proceeds, and varies greatly according to the nature of the plant; for it conſiſts chiefly of the eſſential oil, which comes over in a foul ſtate, and differs in its fixity, denſity, fuſibility, and all its other properties according to the nature and quantity of the eſſential oil which predominates in it. All the products obtained in this way have a peculiar burned ſmell, which chemiſts diſtinguiſh by the name of empyreumatic. If the vegetable contain volatile alkali, or its component parts, this ſubſtance uſually ſublimes when the oil comes over. The elaſtic fluids which paſs into the apparatus of inverted veſſels are chiefly inflammable air, or fixed air, or a mixture of both (probably in combination), which is heavier than pure inflammable air, and burns with a lambent blue flame, inſtead of detonating like that elaſtic fluid. The heat muſt be very gradually raiſed, and the receivers changed from time to time, in this method of decompoſition; otherwiſe the products which come over will be confounded together, and the reſults will of courſe be more fallacious than they would otherwiſe have been. The fixed reſidue conſiſts of charcoal, a

Decompoſition of vegetables by fire.

 ſmall

VEGETABLE PRODUCTS BY FIRE.

ſmall portion of alkali, and a very minute quantity of earth.

Empyreumatic oils.

The empyreumatic oils which come over in theſe diſtillations may all be rendered colourleſs, and ſoluble in ardent ſpirit by rectification. In this manner it appears therefore that the fixed oils of vegetables are converted into volatile or eſſential oils; from which, as well as from other circumſtances, it is rendered probable that theſe oils differ from each other only in the proportion of their component parts.

Charcoal:

The black, ſonorous, brittle, light ſubſtance, called charcoal, uſually retains the figure of the vegetable from which it was produced, unleſs the greater part of the vegetable conſiſted of fluids, which, in their diſſipation, deſtroy the connection of the more fixed parts. In the latter caſe the quantity of charcoal is much leſs than in the former. It is a ſingular fact, that this ſubſtance, when well burned, is a perfect conductor of electricity; though the electric matter is not conveyed at all through wood which is ſimply baked or dried. The charcoal of oily or bituminous ſubſtances is of a light pulverulent form, and riſes in ſoot. This charcoal of oils is called lamp-black.

—conducts electricity:

—reſiſts heat, and abſorbs elaſtic fluids:

Charcoal reſiſts the moſt violent heat in cloſed veſſels. If it be ignited, it abſorbs elaſtic fluids with great avidity as it cools; and it retains the property if cooled by immerſion in mercury, the abſorption being equally conſiderable when it is afterwards expoſed to the air.

—exceedingly combuſtible.

The diſpoſition to be burned, which in the ancient theory is ſuppoſed to conſiſt in the giving out of phlogiſton, and in the modern theory in the abſorption

ſorption of vital air, is ſo great in charcoal, that it performs the reverſe of combuſtion with a great variety of ſubſtances. Thus it converts the vitriolic acid into vitriolic air, by augmenting the proportion of ſulphur; and it is ſtrongly acted on by the nitrous acid, much nitrous air being extricated at the ſame time. The rapidity with which the nitrous acid acts upon perfectly dry charcoal, has been already mentioned. In either of theſe proceſſes, the acid either combines ſuddenly with the phlogiſton of the charcoal, or the vital air of the acid combines with the charcoal itſelf, conſidered as a ſimple ſubſtance.

Charcoal.

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The moſt violent combuſtion of nitre with charcoal, in which the acid is entirely decompoſed, and gives out phlogiſticated air, may be explained in the ſame way by each theory.

Solubility of charcoal.

Alkalis diſſolve charcoal in the dry way; and liver of ſulphur combines very readily with it, either in the dry or humid way. All the metallic ſubſtances hitherto known are leſs combuſtible than charcoal, and conſequently are revived, or reduced to the metallic ſtate, by being heated with this ſubſtance. This, in the ancient theory, denotes that all the metals attract phlogiſton more ſtrongly than charcoal does; but in the new theory the effect is aſcribed to the ſtronger attraction of charcoal, which deprives all metallic calces of the vital air which combined with them during their calcination.

Revivification.

Obſervation.

An important conſequence ſeems to follow from this circumſtance; namely, that there may exiſt many metallic ſubſtances whoſe combuſtibility may be greater than that of charcoal; and which conſe-

VEGETABLE PRODUCTS BY FIRE.

quently are unknown to us as ſuch, becauſe we poſſeſs no means of reducing them. Thus the alkalis and earths may conſiſt of peculiar combuſtible or metallic ſubſtances, either dephlogiſticated, or combined with vital air, by an union which the art of chemiſtry has not yet found means to break.

Combuſtion of charcoal.

When charcoal is expoſed to heat in open veſſels, it burns with a light flame, nearly tranſparent, emitting very little light, and no ſmoke. The reſidue conſiſts of a ſmall quantity of aſhes, which contain fixed alkaline and neutral ſalts. The fixed vegetable alkali is obtained from the aſhes of various plants, under the name of pot-aſh or pearl-aſh, and is not eaſily purified from the neutral ſalts it may be contaminated with. Mineral alkali is obtained by incineration only from marine plants. The neutral ſalts found in the aſhes of vegetables are vitriolated tartar, Glauber's ſalt and ſelenite, common ſalt, and ſalt of Sylvius. Calces of iron and of manganeſe, with an earthy ſubſtance, compoſe the inſoluble reſidue. What this earthy ſubſtance is has not been determined; but it moſt probably conſiſts of ſome inſoluble earthy ſalt, ſuch as phoſphorated lime.

Reſidual ſalts.

CHAP.

CHAP. VII.

CONCERNING FERMENTATION IN GENERAL.

FERMENTATION.

THE word Fermentation, in an enlarged ſenſe, is uſed to denote that change of the principles of organic bodies, which begins to take place ſpontaneouſly as ſoon as their vital functions have ceaſed, and by which they are at length reduced to their firſt principles. This has been diſtinguiſhed into three ſtages; the vinous or ſpirituous, the acid or acetous, and the putrid fermentation; which are ſo called from the principal products obtained during their action. All organized bodies are not ſubject to the three degrees of fermentation. It is aſcertained almoſt beyond a doubt that the vinous fermentation takes place only in ſuch bodies as contain ſaccharine juices. In this the moſt remarkable product is a volatile, colourleſs, light, inflammable fluid, which mixes with water in all proportions, and is called ardent ſpirit. The acetous fermentation is diſtinguiſhed by the product known by the name of vinegar, which is the leaſt deſtructible of the vegetable acids. It does not appear, however, that fermentation is abſolutely neceſſary for the production of this acid, as there are other chemical means by which it may be obtained, or produced. In the putrid fermentation, bodies appear to be reduced into their moſt ſimple parts. Volatile alkali is the product which has been remarked as the chief in this proceſs,

The ſpontaneous decompoſition of vegetables.

Three ſtages of fermentation:

— vinous:

— acetous:

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— putrid:

FERMENTATION.

Stages of fermentation.

procefs, and is no doubt produced by the combination of inflammable and phlogifticated air, which fly off together. The acetous, like the vinous fermentation, is confined to vegetable fubftances; but the putrefactive procefs is moft eminently perceived in animal bodies. Thefe either putrefy immediately; or, if the putrefaction be preceded by either of the other ftages, their duration is too fhort to be perceived. It is confidered as an eftablifhed fact, that the three ftages of fermentation always follow in the fame order, in fuch bodies as are fufceptible of them all; the vinous coming firft, which is followed by the acetous and the putrefactive proceffes.

Conditions or circumftances requifite to the progrefs of fermentation.

The fpontaneous decompofition of bodies is greatly retarded by extreme cold, by fudden drying of the parts, or by prefervation in clofed veffels. The two firft circumftances neceffarily retard the chemical effects, by depriving the parts of that fluidity which is almoft indifpenfably neceffary in chemical proceffes. It will eafily be underftood that the third circumftance will retard the fpontaneous decompofition of bodies, when it is confidered that the atmofphere itfelf is the folvent and receptacle of many of the component parts of bodies with which it is difpofed to combine. In well-clofed veffels, the parts of organized bodies which are difpofed to fly off in the elaftic ftate, are prevented from efcaping; and fuch parts as might form new combinations, by abforbing either the contents, or component parts of the atmofphere, are prevented for want of a free communication. The three conditions for the accomplifhment of fermentation are,

FERMENTATION.

therefore, fluidity or moifture, moderate heat or a due temperature, and the accefs of air: and the fermentation will likewife be modified according to the various component parts of bodies.

Vinous fermentation defcribed, as it takes place in fugar and water.

In defcribing the vinous decompofition of vegetables, it will be of advantage to attend to that of mere fugar and water; the phenomena in thefe being more diftinct, becaufe lefs modified by foreign admixture. If a confiderable quantity of water, holding in folution about one third of its weight of fugar, be expofed to the air at the temperature of about 70 degrees, after the addition of a fmall quantity of yeaft, it foon undergoes a remarkable change. In the courfe of a few hours the fluid becomes turbid and frothy; bubbles of fixed air are difengaged, which rife and break at the furface. The difengagement becomes more and more abundant; mucilage is feparated, part of which fubfides to the bottom; and part, expanded into froth by the elaftic fluid, forms yeaft. During the courfe of feveral days, thefe effects gradually come to their height, and diminifh again; after which they proceed very flowly, but are long before they entirely ceafe. The fermented liquor has no longer the fweet tafte it had before, but becomes brifk and lively, with a pungent fpirituous flavour. Its fpecific gravity likewife is confiderably lefs than before; and, when expofed to diftillation, it affords a light inflammable fpirit. The quantity of ardent fpirit which any fermented liquor will produce, is thought to follow fome proportion of the change its fpecific gravity undergoes in fermentation; but the truth

Yeaft.

Inflammable fpirit.

FERMENTATION.

truth of this has not been clearly afcertained *. Wine, cyder, and beer, are well-known liquors of this kind.

Acetous fermentation.

It is ufual to put fermented liquors into cafks before the vinous fermentation is completely ended; and in thefe clofed veffels it goes on for many months. But if the fermentative procefs be fuffered to proceed in open veffels, more efpecially if the temperature be raifed to 90 degrees, the acetous fermentation comes on. In this the vital part of the air is gradually abforbed; and the more fpeedily, in proportion as the furfaces of the liquor are oftener changed by lading it from one veffel to another. The ufual method confifts in expofing the fermented liquor to the air in cafks, placed fo that the fun may fhine on them; which feems to be of advantage, by raifing the temperature of the liquor. By this abforption of vital air, the inflammable fubftance becomes converted into an acid. If the liquid be then expofed to diftillation, pure vinegar comes over, inftead of ardent fpirit.

Putrefaction.

When the fpontaneous decompofition is fuffered to proceed beyond the acetous procefs, the vinegar gradually becomes vifcid and foul; air is emitted, with an offenfive fmell; volatile alkali flies off; an earthy fediment is depofited; and the remaining liquid, if any, is mere water. This is the putrefactive procefs.

Though fermentation is much better underftood at prefent, in confequence of modern refearches into the

* Richardfon on Brewing.

nature of elaſtic fluids, than it formerly was, it ſtill remains an intereſting object of reſearch. It is not clearly aſcertained what the yeaſt or fermented matter performs in this operation. It ſeems probable that the fermentative proceſs, in conſiderable maſſes, would be carried on in ſucceſſion, from the ſurface downwards; and would perhaps be completed in one part of the fluid before it was perfectly begun in another part, if the yeaſt, which is already in a ſtate of fermentation, did not occaſion the proceſs to begin in every part of the fluid at once. Much remains to be done towards aſcertaining the arrangement and quantity of the component parts of ardent ſpirit: and the theory of fixed air, with the identity of inflammable airs, muſt be aſcertained, before any decided reaſoning can be adopted on this head. It ſeems however that inflammable air, in combination with fixed air in certain proportions, forms ardent ſpirit; that a greater proportion of vital air converts it into vinegar; and that, in the putrefactive proceſs, the inflammable air, the fixed air, and the vital air, are ſeparated from each other, and fly off in the elaſtic ſtate.

FERMENTATION.

The effect of yeaſt in fermentation.

Component parts of ardent ſpirit, &c.

Tartar.

In the fermentation of wine, the tartar, which probably exiſted for the moſt part ready formed in the juice of the grape, is ſeparated, and exhibits the properties which have been already deſcribed in treating of that ſubſtance.

Bread.

The fermentation of bread by leaven is thought to be of a different nature from the vinous fermentation. In this the mucilage of the corn is not previouſly brought into the ſaccharine ſtate. It quickly becomes ſour, FERMENTATION. Bread.

ſour, if the proceſs be not ſtopped by baking; in which particular, the fermentation ſeems to be of the acetous kind. The development of fixed air divides the dough into thin parts, which are more effectually and better baked than they could have been in the ſolid conſiſtent maſs. When bread is fermented by means of yeaſt, the proceſs appears to be of a ſaccharine or vinous nature.

CHAP. VIII.

CONCERNING VINOUS FLUIDS AND ARDENT SPIRIT.

VINOUS FLUIDS.

The making of wine from grapes.

FROM the habits of ſociety, the making of wine, beer, and ardent ſpirits, is become an object of conſiderable importance. Wine is the expreſſed juice of the grape which has undergone the firſt ſtage of fermentation. In this, which in general appears to be the beſt kind of fermented liquor, there are great differences, which depend no leſs on the kind and quality of the fruit than on the proceſs of manufacturing. If the fruit be gathered unripe, the juice will abound with acid, and the wine will be thin and ſharp; but, if the fruit be ripe, it will contain much ſaccharine juice, and the wine will be ſweeter. If the wine be caſked in an early ſtage of the fermentation, much of the ſugar will remain undecompoſed, and the wine will be ſweeter on that account, eſpecially if the fermentation be checked by a conſiderable degree of cold; but, on the contrary, when the progreſs of the fermentation is only impeded by the coercion of the veſſel, which prevents the eſcape of the fixed air, a ſlight increaſe of temperature, ſuch as that of a room in a dwelling-houſe compared with the temperature of a cellar, will cauſe it to proceed with great rapidity as ſoon as the veſſel is opened. Wines in this ſtate are very briſk and lively, from the predominating acidity of the fixed air, which is haſtily diſengaged.

Beer

VINOUS FLUIDS.

The malting of barley:

Beer is the wine of grain. Malt is ufually made of barley. This grain is fteeped for two or three days in water till it fwells, becomes fomewhat tender, and tinges the water of a bright reddifh brown colour. The water being then drained away, the barley is fpread about two feet thick upon a floor, where it heats fpontaneoufly, and begins to grow, by firft fhooting out the radicle. In this ftate the germination is ftopped, by fpreading it thinner, and frequently turning it over for two days; after which, it is again made into an heap, and fuffered to become fenfibly hot, which ufually happens in little more than a day. Laftly, it is conveyed to the kiln, where, by a gradual and low heat, it is rendered dry and crifp. This is malt; and its qualities differ according as it is more or lefs foaked, drained, germinated, dried, and baked. In this, as in other manufactories, the intelligent operators often make a myftery of their proceffes, from views of profit; and others pretend to peculiar fecrets, who really poffefs none.

— of Indian corn.

Indian corn, and probably all large grain, require to be fuffered to grow into the blade, as well as root, before it is fit to be made into malt. For this purpofe, it is buried about two or three inches deep in the ground, and covered with loofe earth; and in ten or twelve days it fprings up. In this ftate it is taken up and wafhed, or fanned, to clear it from its dirt, and then dried in the kiln for ufe.

Brewing of beer.

Beer is made from malt previoufly ground, or cut in pieces by a mill. This is placed in a tun, or tub, with a falfe bottom; hot water is poured upon it, and the whole ftirred about with a proper inftrument. The tempe-

VINOUS FLUIDS.

Brewing of beer.

temperature of the water in this operation, called maſhing, muſt not be equal to boiling; for in that caſe the malt would be converted into a paſte, from which the impregnated water could not be ſeparated. After the infuſion has remained for ſome time upon the malt, it is drawn off, and is then diſtinguiſhed by the name of ſweet wort. By one or more ſubſequent infuſions of water, a quantity of weaker wort is obtained, which is either added to the foregoing, or kept apart, according to the intention of the operator. The wort is then boiled with hops, which give it an aromatic bitter taſte, and are ſuppoſed to render it leſs liable to be ſpoiled in keeping; after which, it is cooled in ſhallow veſſels, and ſuffered to ferment, with the addition of a proper quantity of yeaſt. The fermented liquor is beer; and differs greatly in its quality, according to the nature of the grain, the malting, the maſhing, the quantity and kind of the hops and the yeaſt, the purity or admixtures of the water made uſe of, the temperature and viciſſitudes of the weather, &c.

Metheglin and koumiſs.

Beſides wine and beer, which are made immediately from vegetables; other fermented liquors, containing ardent ſpirit, are made from honey and from mare's milk. The former is called metheglin; and the latter, which is made by the Tartars, koumiſs *. This laſt is made by agitating the milk, at the time when its parts begin to ſeparate, by a fermentation productive of a peculiar acid, called the acid of milk, hereafter to be deſcribed.

* Grieve, in the Edinburgh Tranſactions, vol. i. p. 181.

ARDENT SPIRIT.

Product of vinous liquors by diftillation.

In order to obtain ardent fpirit, nothing more is neceffary than to expofe wine, beer, or any other fermented vinous liquid, to diftillation; and the product which comes over is the ardent fpirit itfelf, contaminated with effential oil. If this be rectified by a fecond diftillation, it becomes much purer. The moft volatile part rifes firft, and is of a lefs fpecific gravity than that which comes over afterwards.

Refidue.

The refidue, after the diftillation of ardent fpirit from wine, is of a deep colour, a rough acid tafte, and depofits cryftals of tartar. The colouring matter is foluble in ardent fpirit. So that it appears, from this imperfect analyfis, that wine confifts of water, ardent fpirit, colouring matter of a refinous nature, fugar, tartar, and tartareous acid, and an aromatic principle.

Strength of ardent fpirit determined by M. Bories.

The ftrength or purity of ardent fpirit is afcertained from its fpecific gravity; for the addition of water renders it heavier. According to M. Bories, whofe Memoir, publifhed at Montpellier in the year 1774, obtained the prize propofed by the ftates of Languedoc in 1772, the fpecific gravity of rectified ardent fpirit repeatedly poured on dry falt of tartar till it would no longer diffolve or liquefy it, was found by many experiments to be as follows:

$$\text{Reaumur's Therm.} + 10^\circ = 820\tfrac{2900}{5055}$$
$$15^\circ = 817\tfrac{65}{5055}$$
$$20^\circ = 813\tfrac{2284}{5055}$$

The fpecific gravities of mixtures, by meafure, of the foregoing fpirit with diftilled water, were as follows:

Tempe-

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Specific gravities of various mixtures of water and ſpirit.

Temperature + 15° Reaumur.

Spirit		Water			Specific gravity
Spirit 10		Water 0			Specific gravity 817 $\frac{65}{5055}$
9	—	1	—	—	844 $\frac{3580}{5055}$
8	—	2	—	—	869 $\frac{4705}{5055}$
7	—	3	—	—	893 $\frac{1895}{5055}$
6	—	4	—	—	915 $\frac{925}{5055}$
5	—	5	—	—	934 $\frac{3630}{5055}$
4	—	6	—	—	951 $\frac{3695}{5055}$
3	—	7	—	—	965 $\frac{1925}{5055}$
2	—	8	—	—	976 $\frac{1320}{5055}$
1	—	9	—	—	987 $\frac{715}{5055}$
0	—	10	—	—	1,000

Obſervations.

Upon the above experiments, which are among the moſt accurate we poſſeſs *, it may be obſerved, that the firſt term, or pure ſpirit, ought to be obtained with an alkali perfectly mild, or ſaturated with fixed air; becauſe, otherwiſe, ſolution and combination of the alkali with the ſpirit might take place. By diſtillation of twenty meaſures of the beſt ardent ſpirit of the ſhops, whoſe ſpecific gravity was 0.836 over a lamp in glaſs veſſels, I found the firſt meaſure which came over had a ſpecific gravity of 820, at the temperature of 71° Fahrenheit; which anſwers to $17\frac{1}{3}$ of Reaumur. This is the ſtrongeſt ſpirit mere diſtillation can afford. When ſtrong ardent ſpirit is added to water, a conſiderable heat is produced, a few bubbles of air are emitted, the mixture contracts in its dimenſions, and acquires a greater ſpecific gravity than would have been deduced by computation.

Strongeſt ardent ſpirit by mere diſtillation.

* See a very valuable ſet of experiments on this ſubject by Mr. Gilpin; of which Dr. Blagden has made a report in the Phil. Tranſ. lxxx. 321.

It

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Requisites or desiderata to ascertain the strength of spirit.

It is by no means an easy undertaking to determine the strength or relative value of ardent spirit, even with sufficient accuracy for commercial purposes. The following requisites must be obtained before this can be well done: The specific gravity of a certain number of mixtures of ardent spirit and water must be taken so near each other, as that the intermediate specific gravities may not perceptibly differ from those deduced from the supposition of a mere mixture of the fluids: the expansions, or variations of specific gravity, in these mixtures, must be determined at different temperatures: some easy method must be contrived of determining the presence and quantity of saccharine or oleaginous matter which the spirit may hold in solution, and the effect of such solution on the specific gravity: and, lastly, the specific gravity of the fluid must be ascertained by a proper floating instrument with a graduated stem, or set of weights; or, which may be more convenient, with both.

Phial proof.

The strength of brandies in commerce is judged by the phial, or by burning. The phial proof consists in agitating the spirit in a bottle, and observing the form and magnitude of the bubbles, which are larger the stronger the spirit. These probably depend on the solution of resinous matter from the cask, which is taken up in greater quantities, the stronger the spirit. It is not difficult however to produce this appearance, by various simple additions to weak spirit.—The proof by burning is also fallacious; because the magnitude of the flame, and quantity of residue, in the same spirit, vary greatly with the form of the vessel it is burned

Proof by burning.

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burned in. If the veſſel be kept cool, or ſuffered to become hot, if it be deeper or ſhallower, the reſults will not be the ſame in each caſe. It does not follow, however, but that manufacturers and others may in many inſtances receive conſiderable information from theſe ſigns, in circumſtances exactly alike, and in the courſe of operations wherein it would be inconvenient to recur continually to experiments of ſpecific gravity.

Characters and component parts of ardent ſpirit:

The moſt remarkable characteriſtic property of ardent ſpirit, is its ſolubility or combination in all proportions with water; a property poſſeſſed by no other combuſtible ſubſtance. When it is burned in a chimney which communicates with the worm-pipe of a diſtilling apparatus, the product which is condenſed is found to conſiſt of water, which exceeds the ſpirit in weight about one eighth part. If ardent ſpirit be burned in cloſed veſſels with vital air, the product is found to be water and fixed air. Whence it is inferred, that ardent ſpirit conſiſts of inflammable air, united either to fixed air, or its acidifiable baſe; and that the vital air, uniting on the one part with inflammable air, forms water; and, on the other, with the baſe of the fixed air, and forms that acid *.

— its uſes and combinations.

A conſiderable number of the uſes of this fluid, as a menſtruum, have already paſſed under our obſervation. The mutual action between ardent ſpirit and

* For an account of theſe experiments, and the precautions neceſſary to be attended to in making them, conſult the Memoirs of M. Lavoiſier, in the Memoirs of the Royal Academy at Paris for 1781 and 1784.

ARDENT SPIRIT.

acids, produces a light, volatile and inflammable oil, called ether. Pure alkalis unite with ſpirit of wine, and form alkaline tinctures. Few of the neutral ſalts unite with this fluid, except ſuch as contain the volatile alkali. The mild fixed alkalis, or combinations of alkali and fixed air, are not ſoluble in it. From the ſtrong attraction which exiſts between ardent ſpirit and water, it unites with this laſt in ſaline ſolutions, and in moſt caſes precipitates the ſalt. This is a pleaſing experiment, which never fails to ſurpriſe thoſe who are unacquainted with chemical effects. If, for example, a ſaturated ſolution of nitre in water be taken, and an equal quantity of ſtrong ſpirit of wine be poured upon it, the mixture will conſtitute a weaker ſpirit, which is incapable of holding the nitre in ſolution; it therefore falls to the bottom inſtantly, in the form of minute cryſtals. Among the neutral ſalts which are ſoluble in ſpirit of wine, the deliqueſcent earthy ſalts ſtand firſt. Moſt ammoniacal ſalts are ſoluble in this menſtruum; and in general it combines more readily with ſuch as have their acid leſs adherent to the neutralizing baſe.

Mutual action of ardent ſpirit and ſalts:

— and ſulphur:

Sulphur does not appear to be acted on more ſtrongly by ardent ſpirit than by water. If ſulphur in ſublimation meet with the vapour of ſpirit of wine, a very ſmall portion combines with it, which communicates an hepatic odour to the fluid. The increaſed ſurface of the two ſubſtances appears to favour the combination.

— and phoſphorus.

Phoſphorus is ſparingly ſoluble in ardent ſpirit, but in greater quantity by heat than in the cold. The addition of water to this ſolution affords an opake milky

ARDENT SPIRIT.

milky fluid which gradually becomes clear by the fubfidence of the phofphorus.

— and earths.

Earths feem to have fcarce any action upon ardent fpirit. Quick-lime however produces fome alteration in this fluid, by changing its flavour, and rendering it of a yellow colour. A fmall portion is probably taken up.

Spirituous folutions.

Soaps are diffolved with great facility in ardent fpirit, with which they combine more readily than with water. None of the metals, nor their calces, are acted upon by this fluid. Refins, effential oils, camphor, bitumen, and various other fubftances, are diffolved with great facility in ardent fpirit, from which they may be precipitated by the addition of water.

CHAP. IX.

CONCERNING THOSE INFLAMMABLE FLUIDS WHICH ARE PRODUCED BY THE ACTION OF ACIDS UPON SPIRIT OF WINE, AND ARE KNOWN BY THE NAME OF ETHER.

ETHER. The making of vitriolic ether.

WHEN ſtrong vitriolic acid is poured upon an equal meaſure of rectified ſpirit of wine, the two fluids unite together, with a hiſſing noiſe and the production of heat, at the ſame time that a fragrant vegetable ſmell is emitted, reſembling that of apples: it is more advantageous, however, to add the acid in ſo gradual a manner as to produce little or no heat. If the mixture be made in a retort, and then expoſed to diſtillation by a well-regulated heat in a ſand-bath, a large receiver being adapted, and kept cool by immerſion in water, or by the frequent application of wet cloths, the volatile products may be ſafely condenſed. Spirit of wine of a fragrant ſmell comes over firſt, and is followed by the ether, as ſoon as the fluid in the retort begins to boil. At this period the upper part of the receiver is covered with large diſtinct ſtreams of the fluid, which run down its ſides. After the ether has paſſed over, volatile ſulphureous acid ariſes, which is known by its white fumes and peculiar ſmell. The receiver muſt now be removed, and another ſubſtituted in its place, care being taken to avoid breathing the penetrating fumes of the acid.

The

The fire muſt at the ſame time be moderated, becauſe the reſidue in the retort is diſpoſed to ſwell. A light yellow oil, called ſweet oil of wine, comes over after the ether, and this is ſucceeded by black and foul vitriolic acid. The reſidue varies in its properties according to the management of the heat. If the fire be much increaſed towards the end of the proceſs, the volatile vitriolic acid which comes over will be mixed with vinegar. If the remaining fluid contained in the retort, after the ether has paſſed over, be not urged farther, it may be made to afford more ether, by the addition of one-third of very ſtrong ardent ſpirit; and this may be repeated ſucceſſively, until near twice the quantity of the ſpirit originally made uſe of has been added.

Diſtillation of vitriolic ether.

Ether of the firſt diſtillation is not pure, but contains ſpirit of wine and ſulphureous acid, which may be ſeparated by the addition of a fixed alkali, and rectifying with a gentle heat. In this rectification, as in all others, the firſt products are the pureſt.

Rectification.

Vitriolic ether is one of the lighteſt and moſt volatile of all denſe and unelaſtic fluids. Its diſſipation into the air is ſo ſudden as to produce an extreme degree of cold. It is highly inflammable, and burns with a more luminous flame, and emits more ſmoke than ardent ſpirit.

Characters.

About ten times its weight of water is ſufficient to diſſolve it. A ſmall proportion of water renders unrectified ether more pure, becauſe it combines with the ardent ſpirit and acid it may contain; but there is reaſon to think, on the other hand, that the ether diſſolves, and combines with part of the water.

Solubility in water.

Little

ETHER.

Combinations of vitriolic ether.

Little is known of the action of this fluid upon faline fubftances. Lime and fixed alkalis do not feem capable of uniting with it. Cauftic volatile alkali combines with it in all proportions; vitriolic acid unites with it, and extricates heat, and from this combination fweet oil of wine may be obtained by diftillation. Nitrous acid effervefces with ether, and renders it more oily. It diffolves camphor very plentifully.

Method of preparing nitrous ether.

The nitrous acid acts very rapidly and powerfully upon ardent fpirit, with which it forms a combination, poffeffing properties fimilar to thofe of the vitriolic ether. The combination takes place without the affiftance of heat, and with fuch facility, that it is even neceffary to add the acid by degrees, and to ufe management for the purpofe of preventing an explofion, which might arife from the heat generated by the mixture. For this purpofe fix ounces of highly rectified fpirit of wine are put into a bottle capable of containing a pound of water, and immerfed in a tub of very cold water, in which it will be advantageous to put three or four pounds of ice broken fmall. Upon the fpirit in this fituation, and kept continually agitated, four ounces of fpirit of nitre, of the fpecific gravity of 1.5, are to be poured, in four or five fucceffive portions. As foon as the mixture is completed, the bottle muft be clofed with a good cork, fecured with leather and packthread, or wire; and the whole muft be left in a place where it may remain undifturbed; no other attention being neceffary than that of renewing the water, from time to time, as it may become heated. In the courfe of two or three hours, the

the tranfparency of the fluid becomes troubled, by an infinity of drops of ether, which are difengaged from every part of its volume. This ether gradually rifes to the furface; and at the end of twenty-four hours it may be feparated from the reft of the liquor by means of a funnel. In opening the phial, it is neceffary firft to pierce the cork with a pointed inftrument, in order that a quantity of elaftic fluid may efcape, which might otherwife fuddenly follow the cork, and carry part of the fluid along with it. The quantity of ether obtained in this manner will be about four ounces.

Methods of preparing nitrous ether.

Characters.

Nitrous ether in this ftate refembles vitriolic ether in its fmell, but it is ftronger and lefs agreeable. Its colour is a light orange; and a portion of the fluid takes the elaftic form, and efcapes with effervefcence whenever the bottle, which contains it, is opened. This ether appears to contain a portion of uncombined acid, upon which thefe phenomena probably depend. It muft be rectified with a fmall addition of alkali, during which operation it lofes near half its weight. The rectified nitrous ether burns with a flame rather more luminous than that of vitriolic ether, at the fame time that it affords a fomewhat larger portion of fmoke, and leaves a black trace behind it. In other refpects it feems nearly to refemble the vitriolic ether.

Nitrous ether may be made with lefs danger, if the acid be diluted, and the quantity of fpirit duly proportioned. It may alfo be had by diftillation of a mixture of the two fluids, in the fame manner as the vitriolic ether; but in this cafe it is requifite that the receiving veffels fhould be uncommonly large, and

that

ETHER.

Methods of preparing nitrous ether.

that every precaution ſhould be taken to prevent their flying in pieces by the force of the elaſtic product which eſcapes: and, upon the whole, it does not ſeem probable that any ordinary degree of precaution would be ſufficient to inſure the operator from danger in this diſtillation. One very eſſential circumſtance conſiſts in uſing the acid in a diluted ſtate.—Nitrous ether has alſo been made by leſs direct proceſſes. If a due proportion of nitre and vitriolic acid be ſucceſſively put into a tubulated retort, the nitrous acid begins to be diſengaged; and, if ſpirit of wine be added to this mixture, nitrous ether comes over. Some degree of precaution is neceſſary in this proceſs; and it might be doubted whether part of the ether which comes over might not have been formed by the vitriolic acid, if moſt of the difficulties were not removed by the uſe of the apparatus, fig. 22. If the tube E be immerſed in a bottle containing highly rectified ſpirit of wine, and the nitrous acid be diſtilled from a quantity of nitre equal in weight to twice the ſpirit of wine, together with as much concentrated vitriolic acid as is equal to half the weight of the nitre; the firſt receiver D will, at the end of the operation, contain fuming nitrous acid; the remote bottle E will contain an ethereal liquor; and the reſidue will be vitriolated tartar. The ethereal ſpirit of wine may then be diſtilled, and the firſt two-thirds of the product reſerved. This reſerved product muſt be diſtilled with one-fifth of its weight of ſmoking nitrous acid, added by degrees to the liquor, in a tubulated retort, by means of a long-necked funnel. Two thirds of this product only are to be taken; which, being rectified from pot-aſh, afford at firſt a quantity of very pure nitrous ether, equal to about one twelfth of the ſpirit made uſe of; and three fourths of the reſt being diſtilled over, conſiſt of a leſs perfect ether, or mineral anodyne liquor. The reſidues of the diſtillations conſiſt of dulcified ſpirit of nitre *.

ETHER.

Nitrous ether.

It is proper, even here, to take notice that all mixtures of the nitrous acid and ardent ſpirit require to be made very gradually, and with great caution, for fear of exploſions.

The reſidue, after diſtillation of nitrous ether, is found, in ſome proportions of the materials and management of the proceſs, to contain no nitrous acid, but an imperfect vinegar, and the acid of ſugar or ſorrel.

Method of preparing marine ether.

The marine acid cannot be combined with ſpirit of wine in the direct way. There are many indirect methods, which conſiſt in applying the dephlogiſticated or aërated marine acid to ardent ſpirit. If to four ounces of common ſalt, and two ounces of pulverized mangaueſe, there be added two ounces of concentrated vitriolic acid, and ſix ounces of the pureſt ardent ſpirit, and the whole be expoſed to diſtillation by a gentle heat, the marine acid will firſt riſe, ſomewhat changed; and, after a conſiderable portion has paſſed over, it muſt be poured back upon the reſiduum, and diſtilled afreſh. In this diſtillation, nearly the half which firſt comes over will be dulcified ſpirit of ſalt; and the greateſt part of the other half, marine ether, which may be ſeparated from the reſt by the addition of water.

* De la Planche, quoted by Fourcroy, iv. 252.

Marine

ETHER.

Marine ether is very tranfparent and volatile, and has nearly the fame fmell as the vitriolic ether. It burns like that fluid, and affords a fmoke, with a fuffocating fmell.

Methods of preparing acetous ether.

It is doubted whether any ethereal fluid can be obtained by the direct union of acetous acid and ardent fpirit. If equal parts of the ftrongeft acetous acid and ardent fpirit be mixed together, and kept for fome days in a well-ftopped glafs, and the mixture be then expofed to diftillation by a gentle heat, the firft half which comes over will, it is faid, confift of an ethereal fluid, from which the ether may be feparated, by the addition of a fixteenth part of vegetable alkali, diffolved in four times its quantity of water. The ether immediately rifes to the top, and commonly amounts to one half of the quantity of the ardent fpirit made ufe of. To the vinegar that remains in the retort half the quantity of ardent fpirit may be added, by which ftill more of the ether may be obtained. The moft certain and incontrovertible method, however, appears to confift in forming the union between the fpirit and acid by indirect means. This may be done by decompofing fome acetous falt, by the addition of a mineral acid, while ardent fpirit is prefent. Thus, if an ounce of alkali faturated with vinegar be diffolved in three ounces of fpirit of wine, and a little more of any mineral acid than is fufficient to faturate the alkali be added, and the mafs be then diftilled, acetous ether will be obtained. Or if eight ounces of fugar of lead be gently dried, to deprive it of its water of cryftallization, which amounts to rather more than one fourth of its weight; if in this ftate it be put

put into a glafs retort, and a mixture of five ounces of vitriolic acid, and eight ounces of fpirit of wine, be poured on it, and the whole expofed to diftillation by a very gentle heat, the firft ounce that paffes over will confift of dulcified acetous acid, the next ounce will be almoft all ether, and the whole quantity of ether produced will be near four ounces.

ETHER.
Acetous ether.

Acetous ether is not nearly fo volatile as the nitrous or vitriolic; it burns with a blue flame, like fpirit of wine.

Ligneous ether.

The empyreumatic acid of wood likewife affords an ether. For this purpofe it may be diftilled from beech, rectified a fecond time, and then faturated with alkali. Three pounds of the acid require about five ounces of alkaline falt. By evaporation to drynefs, with fubfequent folution, filtration, and evaporation, three ounces and a quarter of neutral falt are obtained. The concentrated acid of wood may be difengaged from this by diftillation with two ounces of vitriolic acid; and the quantity of acid of wood thus obtained weighs an ounce and three quarters. By mixing this with an equal quantity of pure ardent fpirit, and diftilling it in a fmall retort, near two ounces and a quarter of ether are obtained.

Saccharine ether.

Equal parts of falt of forrel and ardent fpirit afford about one fifth of their weight of ether. The acid of fugar likewife affords an ether with fpirit of wine, which can hardly be fuppofed to differ from the foregoing, as the two falts are the fame.

Phofphoric ether.

The acid of phofphorus does not produce an ethereal combination by direct diftillation with ardent fpirit: but it is faid that the combination takes place with

ETHER.

with a due mixture of ardent ſpirit, vitriolic acid, and microcoſmic ſalt; the phoſphoric acid being expelled from its baſe, probably in a more dephlogiſticated ſtate than when obtained by ſuffering phoſphorus to deliqueſce in the air.

Ether produced by acid of ants:

The acid of ants produces an ether, with ſpirit of wine, by ſimilar treatment.

— by acid of benzoin.

Acid of benzoin does not produce ether by ſimple ſolution, and ſtanding in ſpirit of wine; but, when one part of the acid of benzoin is diſtilled with three parts of ardent ſpirit, and one half part of common marine acid, the pure ſpirit comes firſt over, and afterwards an ethereal combination, one part of which floats upon water, and the other ſinks to the bottom. This is not more volatile than acetous ether, and burns with a bright flame and ſmoke.

General obſervations.

The converſion of ardent ſpirit into ether, is a proceſs concerning which much remains to be explained. It was formerly thought that the acid did nothing more than deprive the ſpirit of a quantity of water, which was before combined with it, and prevented its exhibiting oleaginous properties. It ſeems aſcertained however, at preſent, that all the ethers contain a portion of that peculiar acid, by whoſe action the ſpirit was changed; as may be ſhewn by ſuffering them to evaporate, or burning them away upon water. It appears therefore that the acid, or ſome of its component parts, combine either with the whole or part of the ardent ſpirit. Some chemiſts have with conſiderable probability aſſerted, that the baſis, or acidifiable principle, of the acid, combines with the ſpirit by the effect of a double affinity; ſo

that

ETHER.

Theoretical obſervations.

that the vital air of the acid combines with a portion of acetous baſis exiſting in the ſpirit, and forms vinegar; another portion combines with the vegetable principles exiſting in ſuch a ſtate as to form the ſaccharine acid; and, laſtly, the acidifiable baſis itſelf, which gave out this vital air, is ſuppoſed to combine with the undecompoſed ſpirit, or vegetable inflammable matter, and riſe in the form of ether. In this view of the ſubject, the nitrous ether is more particularly attended to, and the inferences are extended to other ethers; and oils are ſuppoſed to conſiſt of vegetable inflammable matter, combined with the baſis of an acid *.

* On Ethers, ſee Wiegleb's Chemiſtry, by Hopſon, p. 510, et ſeq.; Scheele's Eſſays, &c.

CHAP. X.

CONCERNING THE ACETOUS ACID.

ACETOUS ACID.

AS moſt of the compounded vegetable acids are convertible, by nitrous acid and by other means, into acid of ſugar, and this laſt into vinegar, it is evident that fermentation is only one of the proceſſes which change the principles of plants into this leaſt deſtructible of vegetable acids. All the vinegar however which is uſed in the common purpoſes of life, is obtained by fermentation. Crude vinegar contains not only that peculiar acid which is diſtinguiſhed by the name of acetous, but likewiſe tartar, oily matter, and frequently ſome of the acids of the fruits from which it may have been procured. It is uſual to purify it by diſtillation. The firſt product conſiſts of a watery fluid, of a lively and agreeable ſmell, though ſcarcely acid. Next follows the acetous acid, commonly called diſtilled vinegar, which has a peculiar ſmell, leſs agreeable than that of the crude vinegar. As the diſtillation proceeds, the volatile product becomes more and more acid, ſomewhat darker coloured, and of an empyreumatic ſmell. The reſidue, after the greateſt part of the fluid has been volatilized, has a deep browniſh red colour, is conſiderably acid, and depoſits a quantity of tartar. By diſtillation to dryneſs, it affords a reddiſh phlegm; more acid; an oil, at firſt light, and afterwards heavy; together with a ſmall quantity of volatile alkali: the reſidual coal contains

Crude vinegar.

Diſtilled vinegar, or acetous acid.

tains much fixed alkali. The quantity of acid product reserved as diftilled vinegar, is commonly about two thirds of the whole. ACETOUS ACID.

Concentration of vinegar by froft.

Vinegar may be concentrated by froft, which feparates its aqueous part. This procefs is particularly applicable to crude vinegar; as, by this means, the grateful flavour, and peculiar properties, are preferved. An ingenious method has been contrived for combining the two proceffes of diftillation and congelation, in concentrating and purifying vinegar. In this way, good wine vinegar is to be diftilled on a water bath. It is effential to referve the phlegm, becaufe the moft fragrant parts come over firft, and are retained in this fluid. The diftilled vinegar and phlegm being then expofed to a freezing cold, and the ice taken out, a concentrated acid remains; which may be completely deprived of its extraneous and oily parts, by repeated rectifications on a water bath. At the beginning of the rectification, a very fpirituous fluid paffes over; which being feparated, and rectified by itfelf, yields a true and fine ether, of a very pleafant fmell, and immifcible with water; which ether is to be added to the ftrong and purified vinegar obtained by the repeated rectifications. The author of this method obferves, that the peculiar and unpleafant fmell of diftilled vinegar proceeds from fome oily parts which pafs over in the diftillation; and that, when thefe parts have been feparated by rectifying the acid concentrated by froft, it again recovers the pleafant fmell of undiftilled vinegar *.

The moft advantageous method of concentrating vinegar.

* Lowitz, in Crell's Annals, quoted by Keir in his Chemical Dictionary, page 32.

ACETOUS ACID.

Combinations of acetous acid:

Pure acetous acid enters into many combinations; and is recovered again by decompofition, though feldom perhaps in its original ftate. In many of its combinations it feems neceffary that it fhould become more ftrongly acidified by attracting vital air from the atmofphere, or from other bodies. This circumftance has not been fufficiently attended to, to admit of a proper diftinction of every cafe in which it may, or may not, happen. We fhall not therefore attempt to point them out, except incidentally, and where the facts are clear.

— with argillaceous earth:

The acetous acid unites with earth of alum, or argillaceous earth, in confiderable quantity, and forms a whitifh faline mafs, which is not cryftallizable. There is however a difagreement among practical chemifts refpecting this combination. Some affert that it takes place very fparingly, and forms fmall needled cryftals. Thefe differences may probably depend on certain circumftances relative to the edulcoration of the earth of alum, after it has been precipitated from its folution by an alkali.

— with calcareous earth:

Calcareous earth is readily diffolved in the acetous acid, and forms a falt, the figure of whofe cryftals varies according to circumftances. It is permanent in the air, unlefs the acid be in excefs; in which cafe it deliquefces. Its tafte is fharp and bitter. When diftilled without addition, the acid quits the earth, and appears in the form of an inflammable vapour, which condenfes into a reddifh brown liquor; and, when rectified, is very volatile and inflammable.

The acetous acid forms a faline mafs by combination

tion with ponderous earth, which does not cryſtallize, but, if dried, attracts moiſture from the air.

Combination of acetous acid with magneſia:

Magneſian earth unites with acetous acid, and affords a very ſoluble ſalt; which, when perfectly ſaturated and evaporated, affords a viſcid maſs, reſembling gum water. Its taſte is ſweetiſh at firſt, but afterwards bitter; and it is ſoluble in ſpirit of wine. Mere heat diſſipates its acid, which may be obtained by diſtillation.

— with vegetable alkali. Foliated earth of tartar.

The combination of vegetable alkali with the acetous acid, produces the ſalt improperly called foliated earth of tartar. In the preparation of this ſalt, it is beſt to add an exceſs of acid. The evaporation muſt be carried to dryneſs on a water bath, in a glaſs or ſilver veſſel. This ſalt cannot eaſily be cryſtallized. Its taſte is penetrating, acrid, and urinous; heat decompoſes it: by diſtillation, it affords an acid phlegm, empyreumatic oil, volatile alkali, and much elaſtic fluid, conſiſting of fixed and inflammable air. The reſidual coal contains much vegetable alkali. If foliated tartar be decompoſed by the addition of vitriolic acid in diſtillation, the quantities being one part of the concentrated acid to two of the ſalt, in a tubulated retort, with a receiver, or apparatus of veſſels adapted, the acetous acid immediately riſes in the elaſtic form, with a ſtrong efferveſcence, and is condenſed in the receiver. This fluid is called radical vinegar, and its acid properties are more intenſe than thoſe of common acetous acid. It is highly probable that this augmentation of acidity is produced by the tranſition of vital air from the vitriolic acid to the acetous; perhaps with the contrary tranſition of phlo-

Radical vinegar.

 giſton.

ACETOUS ACID.

Combinations of acetous acid:

giston. So that, while the acetous acid becomes more acidified, a portion of the vitriolic acid has its acidity diminished, and is converted into sulphureous acid, which comes over, and contaminates the product in the receiver.

— with mineral alkali:

The acetous acid unites perfectly with the mineral alkali, and forms a crystallizable permanent salt. The properties of the acetous salt of mineral alkali do not remarkably differ from those of the foliated earth of tartar. By distillation with vitriolic acid, it affords a purer acetous acid than the foliated tartar does.

— with volatile alkali:

The salt formed by uniting acetous acid with volatile alkali, has been called spirit of Mindererus, or acetous sal ammoniac. It does not easily crystallize; for which purpose it requires to be evaporated to the consistence of syrup, and then exposed to the cold. It soon attracts the moisture of the air, and has a sharp and burning taste. This salt is decomposable by heat; by lime and alkalis, which seize its acid; or by the mineral acids, which seize its base.

— with gold:

The acetous acid has no effect on gold in the metallic state. When added to a solution of gold, it throws it down in the metalline form. The precipitate of gold, effected by a fixed alkali, becomes of a purple colour when digested with the common acetous acid. Radical vinegar dissolves it.

— with silver.

Silver is not acted on by acetous acid; though the calces of this metal, obtained by an alkali from nitrous acid, are soluble.

Platina is likewise insoluble in this acid; though its precipitate from aqua regia, by a fixed alkali, is soluble.

Acetous

Acetous acid does not appear to be affected by mercury; but it diffolves the mercurial calces. The cryftals of this folution have a foliated appearance, refembling that of the acid of borax.

ACETOUS ACID.

Combination of acetous acid with mercury:

Lead is diffolved with the greateft facility by vinegar. The manufacture of cerufe and fugar of lead has before engaged our attention.

— with lead:

Page 270.

Copper is likewife foluble in vinegar, provided atmofpheric air be prefent. The cryftals of acetous acid and copper are improperly called diftilled verdigrife. It is from this falt that radical vinegar has ufually been diftilled by mere heat, without addition. It is at firft coloured by a portion of copper, which comes over; for which reafon it muft be rectified by a gentle heat. The refidue, after diftilling the acetous falt of copper, confifts of the metal in its reguline ftate; whence it is feen that the vital air required to calcine the copper, comes over with the acid, which confequently is in a dephlogifticated or aërated ftate. The laft portion of radical acid which comes over is inflammable, and congealable by cold.

— with copper:

Iron is readily diffolved by the acetous acid, with a flight effervefcence, and the difengagement of inflammable air. This folution depofits much calx of iron by evaporation; and yields a few deliquefcent cryftals when cool. Very little action takes place between common vinegar and iron filings, unlefs by ftanding; during which time, it is probable that the action of the air may contribute in fome degree to the effect.

— with iron.

Compare page 309.

When tin is digefted with the acetous acid, a fmall portion appears to be taken up. The acid becomes

— with tin.

ACETOUS ACID.

turbid, acquires a metallic tafte, and affords a fmall quantity of precipitate by alkalis.

Metallic combinations.

Bifmuth and its calx are foluble in this acid, though fparingly. Nickel is diffolved, and the folution affords green cryftals. Regulus of arfenic is infoluble, but its calx is taken up. The regulus of cobalt is likewife infoluble; its calx affords a pale rofe-coloured folution, which is a fympathetic ink, and receives a green colour from marine acid. Zinc is foluble not only in its metallic and calciform ftates, but alfo, as it is faid, when mixed with other metals: hence it fhould feem ill calculated to defend copper veffels from the action of this vegetable acid. The folution of zinc in common acetous acid affords plated cryftals. Regulus of antimony is very fparingly acted on by the acetous acid; infomuch that it might be judged that no action took place, if it did not impart an emetic quality to the fluid. Manganefe is not acted on by this acid but with great difficulty, though repeated diftillations at length combine the two fubftances. It has not been afcertained whether the acetous acid has any action upon wolfram or molybdena.

Zinc an improper material to defend copper veffels.

BOOK

BOOK II.

PARTICULAR CHEMISTRY.

SECTION VI.

CONCERNING THE PRODUCTS OF THE ANIMAL KINGDOM.

CHAP. I.

A SHORT ENUMERATION OF SUCH ANIMAL SUBSTANCES AS HAVE BEEN EXAMINED BY CHEMISTS.

ANIMAL SUBSTANCES.

Analyſis and arrangement. Page 411—415.

THE general ſtructure and methods of analyſing animal ſubſtances have been already noticed. It therefore remains only to enumerate and deſcribe the ſeveral products of this kingdom, which have engaged the attention of chemiſts. In the arrangement of theſe, as in the vegetable kingdom, we cannot, on account of the imperfect ſtate of our knowledge, have recourſe to the nature of their component parts; but

ANIMAL SUBSTANCES.

Enumeration.

ſhall rather attend to the means by which they are reſpectively afforded or obtained. In this way we may conſider the parts of animals as either,

1. Such as are uſually obtained without deſtroying life. Theſe are milk, eggs, urine, excrement, the matter of perſpiration, ambergris, &c.; wax, honey, gum lac, ſilk, hair, horn, feathers, &c. Or,

2. Such parts of animals as are obtained by deſtroying them, or depriving them of life. Theſe are blood; various ſolids, confounded under the name of fleſh, fat, ſpermaceti; bile, the gaſtric juice, and ſeveral acids; together with calcareous earth, and other ſubſtances, common to the mineral and vegetable kingdoms.

CHAP.

CHAP. II.

CONCERNING MILK, EGGS, HONEY, WAX, LACCA, SILK, HAIR, HORN, ETC.

MILK.

MILK is a well-known fluid, fecreted in peculiar veffels of the females of the human fpecies, of quadrupeds, and of cetaceous animals, and deftined for the purpofe of nourifhing their young. Its appearance and component parts are not altogether the fame in various fpecies of animals; but the differences have not yet been well afcertained. For this reafon, in treating of milk, our attention will be confined to that of the cow, becaufe the moft abundantly met with. This fluid is of a beautiful opake white colour, nearly as limpid as water, and of a pleafant emulfive tafte. Its appearance on the ftage of a microfcope exhibits an infinity of minute opake globules floating in a tranfparent fluid.

General characters of milk.

Cows milk, diftilled on a water bath, affords a taftelefs phlegm of a faint fmell, which is capable of putrefying. A ftronger heat coagulates it. It is fometimes gradually dried into a fubftance which is a kind of faccharine extract, and may again be diffufed in water. By deftructive diftillation, milk affords an acid, a fluid oil, a concrete oil, and volatile alkali. Its refidual coal contains a fmall quantity of vegetable alkali, fome falt of Sylvius, and phofphoric calcareous falt.

Effects of heat on cows milk.

When

MILK.

When milk is left to ſpontaneous decompoſition, at a due temperature, it is found to be capable of paſſing through the vinous, acetous, and putrefactive fermentations. It appears however, probably on account of the ſmall quantity of ardent ſpirit it contains, that the vinous fermentation laſts a very ſhort time, and can ſcarcely be made to take place in every part of the fluid at once by the addition of any ferment. This ſeems to be the reaſon why the Tartars, who make a fermented wine from mares milk, called koumiſs, ſucceed by uſing large quantities at a time, and agitating it very frequently.

Fermentation of milk.

Page 465.

When milk is left expoſed for ſome hours in a ſtate of repoſe, a ſmall quantity of thick fluid riſes to the top, and is known by the name of cream. This contains the fat ſubſtance called butter, which is afterwards ſeparated from it by agitation in the act of churning. The remainder afterwards becomes ſour, and undergoes a coagulation which ſeparates it into two parts—a ſolid curd; and a fluid, called ſerum or whey. This ſour whey contains a peculiar acid, called the acid of milk, and likewiſe a portion of vinegar. The peculiar acid does not riſe in diſtillation, but may be ſeparated by evaporating the filtered whey to one eighth; and precipitating the phoſphoric ſalt by the addition of lime-water, which fully ſaturates its acid: the fluid is then to be diluted with three times its weight of water; and the redundant lime precipitated by ſaccharine acid, in which operation the exceſs of the laſt-mentioned acid may be guarded againſt by the teſt of a ſmall portion of lime-water. This purified liquor muſt then be evaporated to the con-

Cream.

Butter.

Acid of milk.

ſiſtence

fiſtence of honey; and the other foreign ſubſtances it may contain will be ſeparated by the addition of pure ardent ſpirit, which takes up the acid of milk only. The decanted ſolution being then diluted with water, and heated, the ardent ſpirit flies off, and leaves the acid of milk behind, diſſolved in the water.

Acid of milk.

This acid does not afford cryſtals; and, when evaporated to dryneſs, it deliqueſces again by expoſure to air. With vegetable alkali it affords a deliqueſcent ſalt, ſoluble in ardent ſpirit. With mineral alkali it affords a ſalt poſſeſſing the ſame properties. With volatile alkali it produces a deliqueſcent ſalt, which yields much of its alkali by diſtillation before the acid is deſtroyed by heat. With lime, clay, and ponderous earth, it forms deliqueſcent ſalts; but with magneſia it affords ſmall cryſtals, which at length deliqueſce. The acid of milk diſſolves iron and zinc, and produces inflammable air. Copper affords a dark blue ſolution, which does not cryſtallize. Lead is diſſolved after ſome days digeſtion, and affords veſtiges of vitriolic acid. Biſmuth, cobalt, antimony, tin, mercury, ſilver, and gold, are not affected by this acid in a digeſtive or boiling heat. Deſtructive diſtillation decompoſes the acid of milk: water firſt comes over; then a weak acid, reſembling the empyreumatic acid of tartar; afterwards ſome empyreumatic oil, with more of the ſame acid, and alſo fixed air, and the heavy inflammable air. A coal remains in the retort.

Combinations with various ſubſtances.

If any vegetable or mineral acid be added to milk, the curd is ſeparated, and coagulates into one maſs, if the

Curd.

MILK.

Curd.

the mixture be affifted by the application of heat. The curd obtained by means of mineral acid, always manifefts figns of acidity, and is partially foluble in boiling water. If any neutral, earthy, or metallic falt be added to faturation in milk, it likewife feparates the curd. Sugar and gum-arabic produce a fimilar effect. Cauftic alkalis diffolve the curd, by the affiftance of a boiling heat; and it may again be coagulated by the addition of acids.

Manufacture of cheefe:

The coagulation of milk, in the manufacture of cheefe, is effected by the addition of rennet, which is the infufion of the ftomach of a fucking calf in water, prepared in various ways, according to the fancy of the makers. This fluid feems to owe its properties to the gaftric juice of the animal. The feparated curd is wrapped in a cloth with falt, and preffed, to deprive it of the fuperfluous whey; after which, it is preferved for feveral months or years before it is confidered as fit for ufe.

— properties.

Cheefe, when decompofed by deftructive diftillation, affords an alkaline phlegm, an heavy oil, and much volatile alkali. Its refidual coal is difficult to incinerate, and does not afford fixed alkali. By treating it with the nitrous acid, it is found to contain lime and phofphoric acid. Cheefe is not foluble in water. Hot water hardens it.

Sugar of milk.

The faccharine fubftance, upon which the fermenting property of milk depends, is held in folution by the whey which remains after the feparation of the curd in making cheefe. This is feparated by evaporation in the large way, for pharmaceutical purpofes, in various parts of Switzerland. When the whey has been

MILK.

Sugar of milk:

been evaporated by heat, to the confiftence of honey, it is poured into proper moulds, and expofed to dry in the fun. If this crude fugar of milk be diffolved in water, clarified with whites of eggs, and evaporated to the confiftence of fyrup, white cryftals, in the form of rhomboidal parallelopipedons, are obtained.

— Decompofition by heat:

Sugar of milk has a faint faccharine tafte, and is foluble in three or four parts of water. It yields by diftillation the very fame products that other fugars do. It is remarkable, however, that the empyreumatic oil has a fmell refembling flowers of benzoin.

— treatment with nitrous acid.

Twelve ounces of diluted nitrous acid being poured upon four ounces of finely powdered fugar of milk, in a glafs retort, on a fand-bath, with a receiver annexed, the mixture became gradually hot, and at length effervefced violently, and continued to do fo for a confiderable time after the retort was taken from the fire. It is neceffary therefore, in making the experiment, to ufe a large retort, and not to lute the receiver too tight to the retort. After the effervefcence had in fome meafure fubfided, the retort was again placed on the fand-bath, and the nitrous acid diftilled off, till the mafs acquired a yellowifh colour. This yellow fluid exhibited no cryftals. Eight ounces more of the fame nitrous acid were therefore added, and the diftillation again repeated, till the yellow colour of the fluid difappeared. The fluid became infpiffated by cooling; it was therefore rediffolved in eight ounces of water, and filtered. Seven drams and a half of a white powder remained on the filter, and the clear folution afforded cryftals of faccharine acid. The mother water was again treated feveral times with nitrous acid, by which

MILK.

which means the whole was at length changed into faccharine acid.

Peculiar acid of fugar of milk.

The white powder that remained on the filter was found to be combuftible like oil in a red hot crucible, without leaving any mark of afhes behind. It was foluble in fixty times its weight of boiling water; and one fourth part feparated by cooling, in the form of very fmall cryftals. The remaining mafs being then collected, by evaporating the greateft part of the water, left behind a fmall portion of the acid of fugar, of which it had not been fo exactly deprived by edulcoration on the filter. From thefe circumftances it appeared that the white matter was a falt; and, upon examination, it was found to be an acid, poffeffing the following properties:

Combinations.

With all the foluble earths it forms falts infoluble in water. It difengages fixed air from the mild alkalis. With vegetable alkali it forms a cryftallizable falt, foluble in eight times its quantity of boiling water, and feparable for the moft part by cooling. With the mineral alkali it forms a falt which requires only five parts of boiling water for its folution. Both thefe falts are perfectly neutral. When faturated with volatile alkali, it forms a falt which, after being gently dried, has a fourifh tafte. It does not perceptibly act on the metals; but forms with their calces, in folution, falts of very difficult folubility, which are therefore precipitated *.

The principles of milk appear to be united together partly in a chemical, and partly in a mechanical

* On milk and its acid, and on the acid of the fugar of milk, confult the Chemical Effays of Scheele.

manner;

MILK.

manner; and the butter ſeems to riſe to the top in conſequence of the greater ſpecific gravity of the whey through which it is diſperſed. Cream conſiſts of butter mixed with much whey and curd. It is generally thought that the ſeparation of the butter by churning is effected ſimply by the agitation, which cauſes the fatty particles to ſtrike againſt each other, and coagulate into larger maſſes. There ſeems however ſome reaſon to think that a chemical effect takes place in this operation; in which the intimate mixture of atmoſpheric air with the fluid may perhaps have ſome effect.

Separation of butter from cream:

Butter appears to be of the nature of fat oils; but is conſidered by moſt nations as infinitely preferable to them, as an article of food. By diſtillation on a water-bath it gives out the aqueous fluid which, from the manner of its fabrication, is diſtributed through its maſs. Its products, by deſtructive diſtillation, nearly reſemble thoſe of other oils. They conſiſt of an acid of a ſtrong and penetrating ſmell, a fluid oil, and a concrete oil of the ſame ſmell as the acid. Theſe oils, like others obtained in ſimilar circumſtances, may, by repeated rectifications, be converted into volatile oils, of the nature of thoſe which are called eſſential. In other reſpects, butter poſſeſſes the ſame properties, and may be applied to the ſame uſes as fat oils. It becomes rancid by ſpontaneous decompoſition, which developes its acid; and with fixed alkalis it forms ſoap.

—its properties.

The eggs of birds conſiderably reſemble milk in their component parts, though their peculiar ſtructure

Eggs.

MILK.

and organization conſtitute a great and eſſential difference, applicable to the purpoſes of generation, into which our preſent views do not require us to proceed. The white of egg does not greatly differ from the curd of milk or cheeſe. When it is mixed with water, it forms a coagulum or curd by the addition of acids. Heat coagulates the white of egg, without depriving it of weight; which is a very ſingular fact, and has not yet been well explained. The white of egg however appears to differ, in ſome reſpects, from curd. It is ſaid to afford a ſmall portion of ſulphur by ſublimation; and it contains the mineral alkali in a diſengaged ſtate.

Reſemblance between white of egg and curd of milk.

Yolk of egg.

The yolk of egg appears to be an animal emulſion, which is diffuſible in water. It contains an oil, which may be ſeparated by drying, and afterwards ſubjecting it to preſſure.

Honey and wax.

Honey and wax may be conſidered as animal ſubſtances, becauſe afforded by the bee; though it is not improbable but theſe laborious inſects may extract them from the veſſels of plants, and depoſit them in their hives without alteration.

Purification of honey.

Honey which is purified by ſolution and cryſtallization, perfectly reſembles the ſaccharine juices of vegetables which have undergone the like treatment. It affords the ſame product as ſugar by deſtructive diſtillation. Nitrous acid converts it into the ſaccharine acid, and its aqueous ſolution is ſuſceptible of all the ſtages of fermentation. It is accordingly, as we have before obſerved, made uſe of in the preparation of a vinous liquor.

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Wax

Wax is a concrete ſubſtance, which greatly reſembles the more ſolid fixed oils, and unites with oily ſubſtances in all proportions. Its products, by deſtructive diſtillation, are the ſame as thoſe of other fat ſubſtances. The concreſcible oil obtained by diſtillation of this ſubſtance, is called butter of wax. Bees-wax is of a yellow colour, but becomes white by expoſure to air: this effect takes place only at or near the ſurface or place of contact; for which reaſon the bleachers of wax find it neceſſary to renew the ſurface frequently. This is done either by cauſing the melted wax to paſs through a number of holes in the bottom of a veſſel into another veſſel of water, by which means it undergoes that kind of diviſion which, in metallic bodies, is called granulation; or it is gently poured upon a wooden cylinder, which is turned round in a veſſel filled with water to ſuch a height, that half of the cylinder is immerſed. In this way, the wax forms a number of thin flakes, that do not adhere to each other, but may be taken off, and expoſed to the action of the air. The dephlogiſticated or aërated marine acid bleaches wax very ſpeedily; from which fact it appears that the wax owes its whiteneſs, and the greater conſiſtency it acquires, to an abſorption of the vital part of the atmoſphere. Wax ſeems to differ from tallow, or concrete oil, principally in this circumſtance: and this laſt ſubſtance becomes likewiſe harder and whiter by long expoſure to the air, in thin maſſes; as, for example, when it is ſpread out upon the ſurface of water. Wax being already combined with a portion of vital air, does not burn with ſo luminous a flame as tallow or oil. But it poſſeſſes a very

WAX. Diſtillation of wax.

Butter of wax.

Bleaching.

Difference between wax and tallow.

WAX.

great advantage in the fabrication of candles, which arifes from the circumftance of its freezing point being placed at a confiderably higher temperature than thofe of either of the other two fubftances.

An explanation of the chief advantage of wax candles compared with thofe of tallow.

To explain this advantage, it muft be confidered, that oils do not take fire, unlefs they be previoufly volatilized by heat. The wick of a candle, or lamp, anfwers this purpofe. The oil rifes between the fibres of the wick by the capillary attraction. Heat is applied to the extremity of the wick, which volatilizes and fets fire to a portion of the oil. While this is diffipated by combuftion, another portion paffes along the fibres, and fupplies its place by becoming heated and burned likewife. In this way a conftant combuftion is maintained. It muft be remarked, however, that a candle differs from a lamp in one very effential circumftance, namely, that the oil, or tallow, is liquefied only as it comes to be in the vicinity of the conflagration; and this fluid is retained in the hollow of the part which is ftill concrete, and forms a kind of cup. For this reafon, it is found neceffary that the wick fhould not be too thin; becaufe, in this cafe, it would not carry off the fluid as faft as it becomes fufed; and the confequence would be, that it would run down the fides of the candle: and, as the inconvenience arifes from the fufibility of the oil, it is plain that a more fufible candle will require a larger wick; or that the wick of a wax candle may be made thinner than that of one of tallow.

The difference of effect, in illumination, between a thick and a thin wick, cannot be better fhewn than by remarking the appearances produced by both. When

 a candle

WAX.

The use and effects of the wick in candles.

a candle with a thick wick is firft lighted, and the wick fnuffed fhort, the flame is perfect and luminous, unlefs its diameter be very great; in which laft cafe, there is an opake part in the middle, where the combuftion is impeded for want of air. As the wick becomes longer, the fpace between its upper extremity and the apex of the flame is diminifhed; and confequently the oil which iffues from that extremity, having a lefs fpace of ignition to pafs through, is lefs completely burned, and paffes off partly in fmoke. This evil continues to increafe, until at length the upper extremity of the wick projects beyond the flame, and forms a fupport for an accumulation of foot, which is afforded by the imperfect combuftion. A candle, in this fituation, affords fcarcely one tenth of the light which the due combuftion of its materials would produce; and tallow-candles, on this account, require continual fnuffing.—But, on the contrary, if we confider the wax candle, we find that, as its wick lengthens, the light indeed becomes lefs, and the cup becomes filled with melted wax. The wick however, being thin and flexible, does not long occupy its place in the center of the flame; neither does it, when there, enlarge the diameter of the flame fo as to prevent the accefs of air to its internal part. When its length is too great for the vertical pofition, it bends on one fide; and its extremity, coming into contact with the air, is burned to afhes; excepting fuch a portion as is defended by the continual afflux of melted wax, which is volatilized, and completely burned, by the furrounding flame. We fee therefore that the difficult fufibility of wax renders it practicable to burn a large quantity of

 fluid

WAX. LACCA. fluid by means of a fmall wick; and that this fmall wick, by turning on one fide in confequence of its flexibility, performs the operation of fnuffing upon itfelf, in a much more accurate manner than it can ever be performed mechanically.

Wax is not foluble in ardent fpirit.

Stick-lac, fhell-lac, and feed-lac:

Lac, or lacca, is a fubftance well known in Europe, under the different appellations of ftick-lac, fhell-lac, and feed-lac. The firft is the lac itfelf, which is a brown femi-tranfparent fubftance, in pretty confiderable lumps, with woody parts adhering to it. Seed-lac is the ftick-lac broken in pieces, and appearing in a granulated form. Shell-lac is the fubftance which has undergone a fimple purification.

—its production.

Lac is the product of an infect *, which depofits its eggs on the branches of a tree called Bihar, in Affam, a country bordering on Thibet, and elfewhere in India. It appears defigned to anfwer the purpofe of defending the eggs from injury, and affording food for the maggot in a more advanced ftate. It is formed into cells, finifhed with as much art and regularity as an honey-comb, but differently arranged; and the inhabitants collect it twice a year, in the months of February and Auguft. For the purification, it is broken into fmall pieces, and put into a canvas bag of about four feet long, and not above fix inches in circumference. Two of thefe bags are in conftant ufe, and each of them held by two men. The bag is placed over a fire, and frequently turned, till the lac is liquid enough to pafs

* For a defcription, confult Kerr, in the Phil. Tranf. vol. lxxi. p. 374.

through its pores; when it is taken off the fire, and twisted in different directions by the men who hold it, at the same time dragging it along the convex part of a plantain tree prepared for that purpose; and, while this is doing, the other bag is heating, to be treated in the same way. The mucilaginous and smooth surface of the plantain tree prevents its adhering; and the degree of pressure regulates the thickness of the coating of lac, at the same time that the fineness of the bag determines its clearness and transparency *.

LACCA. Purification of lac.

Lac is not entitled to arrangement either with oils, resins, or gums. It is not soluble either in water, or in fat oils. Some essential oils appear to extract a dilute tincture. The action of the acids upon lac, either when concentrated or diluted, does not seem to be considerable; but this requires more particular examination, especially as far as relates to the nitrous acid. Ardent spirit acts but feebly on this substance. By standing upon it in the cold, it forms a clear tincture, apparently by dissolving only a part of its principles; but, when digested in a moderate heat, the whole of the lac unites with the spirit, and forms a turbid mixture, or imperfect solution, of a gummy appearance, which does not afterwards become clear. In this way, however, with judicious management, it appears practicable to form a very hard opake varnish, resembling that of China or Japan. The principal use of lac is in the manufacturing of sealing-wax, and in dying scarlet. For this last purpose, half a dram of powdered comfrey root is to be boiled in a quart of

Characters.

Hard varnish.

* Saunders, in Phil. Transf. vol. lxxix.

LACCA. SILK. Uses of lac.

water for a quarter of an hour, and some powdered gum lac digested in the decoction for two hours. The tincture appears of a fine crimson colour; and the remaining lac, if the quantity of liquor has been sufficient, is of a pale straw colour. The clear tincture being then poured off, and a solution of alum gradually added, the colouring matter subsides, in the form of one of the powders called lakes, which amounts to about one fifth part of the weight of the lac. This fecula is dissolved in warm water, with the addition of a proper quantity of the solution of tin in aqua regia: and the liquor, which is of a fiery red colour, is then to be poured into boiling water, impregnated with salt of tartar, or the mild fixed vegetable alkali. The bath, thus formed, is a good scarlet dye for woollens, though less lively than that of cochineal.

Lewis on Neumann.

Silk, and the acid of silk-worms.

Silk is a well-known substance, which serves as a nidus for the chrysalis of the silk-worm. Its extensive utility, when contrasted with the small prospect of advantage which its appearance in the crude state seems to afford, may serve to stimulate our industry in the examination of other natural products; many of which, though neglected at present, might, on enquiry, be found equally beneficial to society. This substance seems to hold a middle rank between animal and vegetable matters. It affords volatile alkali by distillation, and gives out phlogisticated air when treated with nitrous acid. By distilling the nitrous acid from this substance, the acid of sugar is obtained, and likewise a peculiar oil. The phalæna, or moth of the silk-worm, ejects a liquor which appears to contain

SILK. WOOL.

contain a peculiar acid, hitherto little examined. It is obtained in a ſtate of purity by infuſing the chryſalides in ardent ſpirits, and ſubſequent evaporation.

Animal excreſcences.

The hair and wool of animals do not ſeem to differ greatly from ſilk. They afford much acid of ſugar, when treated with nitrous acid. It is probable that horns, feathers, and other ſimilar excreſcences of animals, are nearly of the ſame nature.

CHAP.

CHAP. III.

CONCERNING THE EXCREMENTITIOUS PARTS OF ANIMALS.

EXCREMENTITIOUS MATTERS.

Urine and fecal matter.

THE fubftances which are rejected out of the bodies of animals, as ufelefs, are urine, and the fecal matter, or excrement. Thefe differ in the various fpecies of animals, according to their refpective natures and food. But little attention has been paid by chemifts to the urine or excrements of any animals except the human fpecies. We have already had occafion to mention the contents of urine, in treating of the phofphoric acid, in our account of the mineral kingdom; and fhall therefore, in the prefent place, confine our remarks to that peculiar depofition which is known by the name of the urinary calculus, or ftone of the bladder.

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Stone of the bladder.

The matter which forms thefe hard concretions is found in all urine; and is depofited by cooling, after the greateft part is evaporated. Heat again diffolves it. In about three hundred times its weight of boiling water it is either totally foluble, or it leaves a very inconfiderable refidue, which feems to be an impurity. As the fluid becomes cold, moft of the calculus is again feparated in fine cryftals. The vitriolic acid diffolves it with effervefcence; the marine acid does not appear to act upon it; and the nitrous acid totally diffolves it. This folution affords no precipitate by the acid of fugar, though the vitriolic acid throws down a fmall portion of felenite: whence it appears that the calculus

calculus contains ſome lime. Pure alkalis diſſolve it, as does likewiſe lime-water. By deſtructive diſtillation, the calculus affords fluid volatile alkali, and a ſublimate of a brown colour, which by a ſecond ſublimation becomes white. This has a ſouriſh taſte, is eaſily ſoluble in boiling water, and alſo in ardent ſpirit.

EXCREMENTITIOUS MATTERS.

Acid of the ſtone of the bladder.

From the above, and other experiments, it appears that the calculus conſiſts of an acid of a volatile nature, together with ſome gelatinous or oily matter, and a ſmall portion of lime. The acid itſelf may probably be a compound ſalt with exceſs of acid, ſimilar to the combinations of mineral alkali and phoſphoric acid, vegetable alkali and tartareous acid, and ſome others which were conſidered as ſimple acids, until chemiſts had deviſed means of ſeparating their component parts. We ſee therefore that the analyſis of the ſtone of the bladder has not yet been perfectly made.

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However important the knowledge of the component parts of fecal matter may be, to facilitate our acquaintance with the animal ſyſtem, it may eaſily be imagined that the purſuits of the majority of chemiſts would be directed to departments of the ſcience; which promiſed effects of a leſs diſguſting nature. We poſſeſs but one ſet of experiments made on this ſubſtance, by Homberg, at the beginning of the preſent century. This philoſopher, in conſequence of alchemiſtical information, inſtituted a ſet of operations upon the fecal matter of men fed entirely upon bread of Goneſſe *, and Champagne wine. He found that,

Homberg's experiments on human excrement.

* A ſmall town near Paris, where the moſt excellent bread is made.

when

EXCREMENTITIOUS MATTERS.

Homberg's experiments on the human fecal matter.

when recent, it afforded, by diftillation to drynefs, an aqueous, clear, infipid liquor, of a difagreeable odour, which contained no volatile alkali; but, by continuing to diftil the refidue by a graduated fire, he obtained fluid and concrete volatile alkali, a fetid oil, and a coaly refidue; fubftances which this imperfect method of analyfis exhibits with every kind of animal fubftance.

The human fecal matter, by lixiviation in water, filtration, and fubfequent evaporation, afforded an oily falt refembling nitre, which was fufed on ignited coals, and took fire when heated to a certain degree in clofed veffels. The fame fecal matter, after it had undergone a complete putrefaction for forty days, in the gentle heat of a water-bath, afterwards afforded by diftillation a colourlefs oil without fmell, which was the thing fought after; but it did not fix mercury, as he had been led to expect.

Imperfect as this examination is, it is rendered ftill lefs generally applicable by the peculiar nature of the aliments from which the matter originated. For it cannot be doubted but that, as the excrements are the refidue of the food taken, they will differ according to the nature of that food; as is indeed fufficiently evinced from their more obvious qualities.

Ambergris.

It is at prefent a general opinion *, that ambergris is an excrementitious fubftance, voided by the phy-

* Chiefly grounded on the enquiries and obfervations of Dr. Swediar, in the Phil. Tranf. for 1783. Mr. Magellan however mentions an undoubtedly vegetable ambergris, gathered from the tree by M. Aublet, and examined by Rouelle. Cronftedt's Mineralogy, p. 458.

feter

EXCREMENTITIOUS MATTERS.

feter macrocephalus, or fpermaceti whale. Ambergris is found in the fea, near the coafts of various tropical countries; and is either white, black, afh-coloured, yellow, or grey, with black or yellow fpecks. A flight warmth foftens it, like pitch; by a greater heat it takes fire; and its chemical products refemble thofe of bitumens, among which it has ufually been ranked. Oils diffolve it; as does likewife ardent fpirit, if its quantity be twelve times that of the ambergris, and its temperature boiling. An addition of effential oil promotes the folution.

Characters of ambergris.

Various other matters are rejected from animals; fuch as the matter of perfpiration, the nafal mucus, tears, &c. But as none of thefe have been examined, we fhall avoid entering into any detail of their obvious properties.

Matter of perfpiration, &c.

CHAP.

CHAP. IV.

CONCERNING THE BLOOD, AND THE OTHER FLUID OR SOLID MATTERS, OF WHICH ANIMALS ARE FORMED.

PARTS OF ANIMALS.

The blood:

— differences.

THE fluid which firſt preſents itſelf to obſervation when the parts of living animals are divided or deſtroyed, is the blood, which circulates with conſiderable velocity through veſſels called veins and arteries, diſtributed into every part of the ſyſtem. It can ſcarcely admit of doubt but that the component parts, or immediate principles of the blood, muſt differ in the various and exceedingly diſſimilar genera and ſpecies of animals which occupy the land and waters of the globe; and that there are likewiſe differences in the ſtate or compoſition of this fluid in the ſame animal, according to its ſtate of health, as well as the ſituation of the veſſels from which it may be extracted. Theſe differences can be aſcertained only by the united efforts of the anatomiſt and the chemiſt. But as the difficulty and extent of the ſubject have hitherto prevented any conſiderable progreſs, it becomes an object of neceſſity to confine our attention to the blood of man, or of ſuch quadrupeds as afford this fluid in a ſtate not obviouſly different from that of the human ſpecies.

Recent blood is uniformly fluid, and of a ſaline or ſlightly ferruginous taſte. Under the microſcope it appears

PARTS OF ANIMALS.

appears to be compofed of a prodigious number of red globules fwimming in a tranfparent fluid. After ftanding for a fhort time, its parts feparate into a thick red matter, or craffamentum, and a fluid called ferum. If it be agitated till cold, it continues fluid; but a confiftent polypous matter adheres to the ftirrer, which by repeated ablutions with water becomes white, and has a fibrous appearance: the craffamentum becomes white and fibrous by the fame treatment. If blood be received from the vein in warm water, a fimilar filamentous matter fubfides, while the other parts are diffolved. Alkalis prevent the blood from coagulating; acids, on the contrary, accelerate that effect. In the latter cafe the fluid is found to contain neutral falts, confifting of the acid itfelf united with mineral alkali, which confequently muft exift in the blood, probably in a difengaged ftate. Ardent fpirit coagulates blood. On the water-bath, blood affords an aqueous fluid, neither acid nor alkaline; but of a faint fmell, and eafily becoming putrid. A ftronger heat gradually dries it, and at the fame time reduces it to a mafs of about one eighth of its original weight. In this ftate it flightly attracts the humidity of the air, and effervefces with acids; but by a longer expofure, for fome months, it becomes covered with an efflorefcence of mild mineral alkali. By deftructive diftillation this animal fluid affords a watery liquor, holding in folution a neutral falt, with excefs of volatile alkali, but whofe acid part has not been well afcertained: next follows a light oil, a denfe coloured oil, and foul or oleaginous volatile alkali. The refidue is a coal of very difficult incineration, containing common falt, mineral

Characters of the blood.

Habitudes with acids, &c.

Diftillation.

PARTS OF ANIMALS.

mineral alkali, and an earth, which is probably a combination of lime and phofphoric acid.

Serum of blood: The ferum of blood exhibits marks of a difengaged alkaline falt, and is greatly difpofed to putrefy. It unites with water in all proportions, and forms a milky fluid, which may be coagulated by acids or ardent fpirit. An increafe of temperature caufes ferum to become confiftent, with little or no lofs of weight, in the fame manner as the white of egg; and it is accordingly ufed for the fame purpofe in clarifying liquids. From a variety of experiments, it appears highly probable that white of egg, ferum of blood, and the pure curd of milk, do not effentially differ from each other: and to thefe we may perhaps add the vegetable gluten, which confiderably refembles cheefe.

— refembles white of egg, curd, and vegetable gluten:

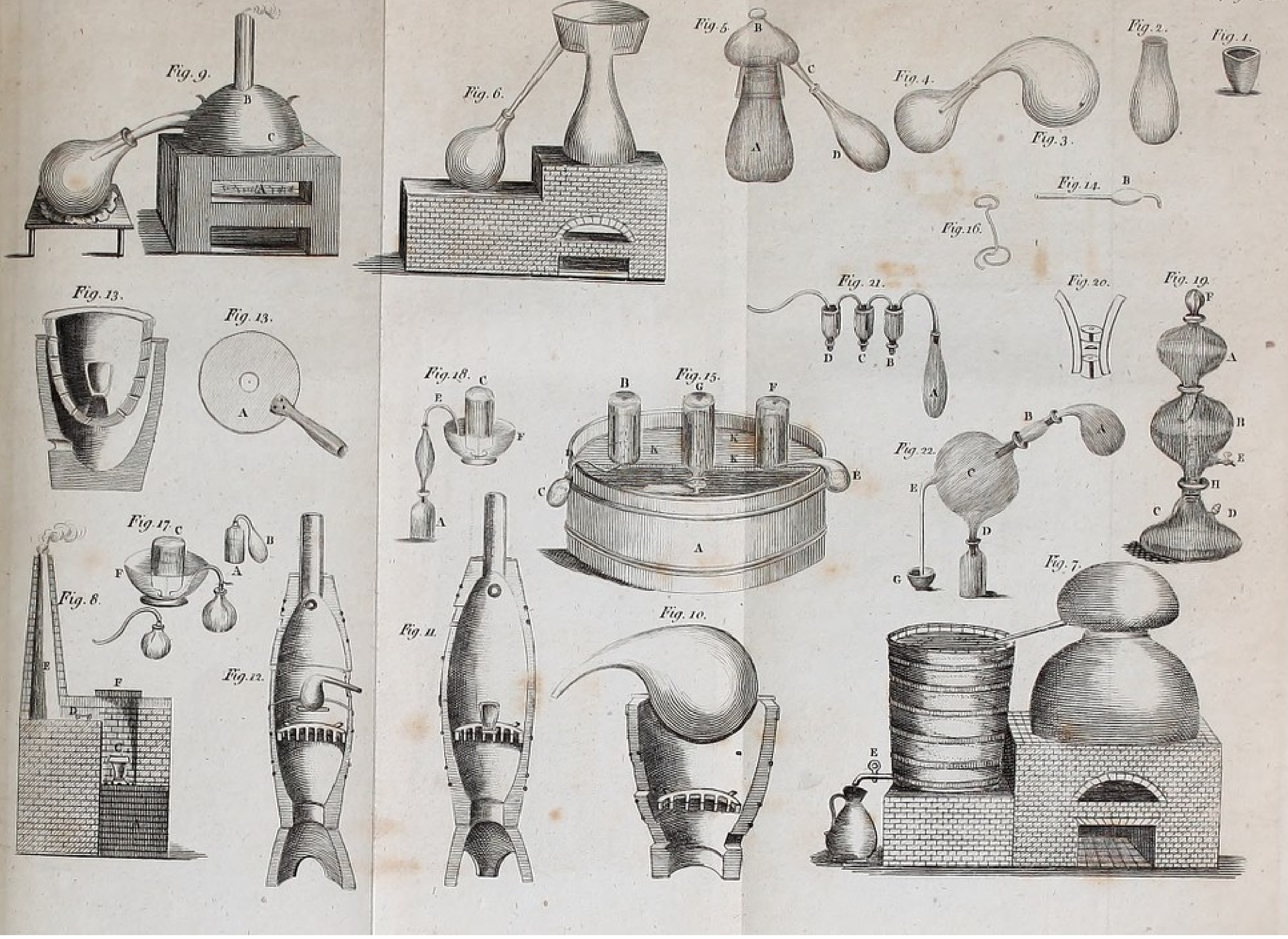
— with alkalis and acids: Alkalis render the ferum of blood more fluid; acids coagulate it, and exhibit the neutral falt they would have produced by direct combination with mineral alkali. The coagulum affords, by diftillation, phlegm, mild volatile alkali, and a thick fetid oil; and the refidue affords mild mineral alkali. Thefe products are the fame as are afforded by the ferum itfelf.

— with ardent fpirit: Serum is alfo coagulated by ardent fpirit, merely by the lofs of part of its water. When rendered concrete

— nitrous acid. by heat, and expofed to the action of nitrous acid, it affords phlogifticated air by a flight heat, which is followed by nitrous air; and the refidue affords acid of fugar, together with a fmall portion of acid of apples.

Craffamentum. The craffamentum of blood, when treated in the way of diftillation, becomes dry and brittle, at the fame time that it emits an alkaline phlegm; this is followed by an empyreumatic ftinking oil, and concrete volatile alkali.

To face page 512.



alkali. A ſpungy brilliant coal remains, which by treatment with vitriolic acid is found to contain mineral alkali and iron, as appears by the production of Glauber's ſalt and martial vitriol: coaly matter and phoſphorated lime are then left behind.

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Fibrous part of blood:

The fibrous matter, which is obtained by waſhing the red part of the blood, reſembles the ſerum in many of its properties; though it differs from it in not being ſoluble in water, in becoming hard by a very gentle heat, and in not combining with alkalis. Acids unite with it, and in particular the nitrous acid diſſolves it, and extricates phlogiſticated and nitrous air; while the reſidue, by evaporation, affords acid of ſugar in cryſtals, a peculiar oil in flocks, and the phoſphoric ſalt of lime. Its volatile products by deſtructive diſtillation are nearly the ſame as thoſe of ſerum: but its reſidue contains no ſalt, except the combination of lime and phoſphoric acid; the other ſalts it might have contained having probably been carried off during the waſhing. Marine acid forms a green jelly with the fibrous parts of the blood.

— with acids.

Deſtructive diſtillation.

Soft parts of animals.

The ſoft and flexible parts of animals appear to be compoſed of principles greatly reſembling thoſe of the blood. When they are boiled in water, the fluid extracts that peculiar animal ſubſtance which is known by the name of jelly or glue. This is afforded by the white parts moſt plentifully, though it is found in almoſt every part of the animal ſolids. Its appearance and inſipidity, together with its other obvious properties, are well known. It is ſoluble in water, in all proportions; is more fluid when hot than when

Jelly or glue.

PARTS OF ANIMALS.

Jelly or glue.

cold. Alkalis and acids both diffolve it. By fpontaneous decompofition it firft becomes acid, and foon afterwards putrefies. By deftructive diftillation it affords an alkaline phlegm, an empyreumatic oil, and a fmall quantity of volatile alkali. The refidual coal is voluminous, not eafily incinerated, and contains common falt, with the phofphoric falt of lime. The habitude of the nitrous acid with glue, or jelly, is the fame as with other animal fubftances; phlogifticated air and nitrous air are difengaged, and the refidue affords acid of fugar.

Analyfis of the flefh of animals.

Befides the parenchymatous and cellular fubftance of which the mufcles of animals are formed, their veffels contain fluids poffeffed of various properties. Thefe may be obtained by preffure, and the judicious application of water and ardent fpirit, either with or without heat. If flefh be wafhed in cold water, a portion of blood and gelatinous matter, together with faline matter, are extracted: the refidue being digefted in ardent fpirit, is by that means deprived of an extractive or faponaceous fubftance; and fubfequent ebullition in water diffolves the gelatinous part, at the fame time that it deprives it of fuch portions of extract and falt as had been defended from the action of the two former folvents. The fat is alfo liquefied by this operation, and arifes to the furface. By flow evaporation of the aqueous folution, made in the cold, the albuminous part, or ferum, coagulates, and may be feparated on the filter: the filtered liquor will afford its falt by evaporation: the fpirituous folution depofits the extractive matter by evaporation: and the decoction affords the jelly, with the fat oil, which fwims

at

at the furface and congeals by cooling. The remaining folid fubftance confifts merely of the fibrous matter, which is white, infipid, and infoluble in water. This affords much volatile alkali, and a very fetid oil, by diftillation; and it gives out a large quantity of phlogifticated air when treated with nitrous acid. In a word, it has all the characters of the fibrous part of the blood, and is probably formed by the depofition of that fubftance *.

Analyfis of the flefh of animals.

The extractive or faponaceous matter obtained by the evaporation of the fpirit, is foluble likewife in water; it fwells up and liquefies by heat, and emits a fmell fomewhat refembling that of burned fugar: it is this fubftance which predominates in the brown cruft that covers the furface of roafted meat. The falt afforded by the decoction of flefh has not been perfectly examined; but it feems to confift of the phofphoric acid, united partly with the vegetable alkali, and partly with lime.

Fat of animals.

The fat of animals is a fubftance of the fame nature as thofe oils, which are called fat oils in the vegetable kingdom. Its confiftence is various in different animals, and in different parts of the fame animal. The fat of the human fpecies and of quadrupeds is confiftent, and of a white or yellowifh colour; the fat of the internal parts being ufually firmer than that which is placed among the mufcles. It poffeffes all the characters of vegetable fat oils; though the crude fat of animals appears to contain a confiderable quantity of

Page 421.

* Foureroy, iv. 427.

muci-

mucilage or jelly peculiar to that kingdom, which may for the moſt part be waſhed off by agitation in a large quantity of hot water.

Acid of fat.

The acid of fat is conſidered as belonging to the animal kingdom, though indeed it is no leſs abundant in the fat oils of vegetables. It may be obtained by diſtillation. Or otherwiſe a quantity of ſuet may be melted, and mixed with quick-lime: as ſoon as the mixture is cold, it muſt be boiled in a large quantity of water. After filtration and evaporation, the calcareous ſalt formed by the combination of that earth with the acid of the fat, is obtained of a brown colour. A ſlight calcination in a crucible renders it purer, by the deſtruction of a portion of inflammable matter; and by ſolution, filtration, and the addition of a certain quantity of fixed air to precipitate the ſuperfluous lime, a clear ſolution of the acid of fat, neutralized with calcareous earth, is obtained. Evaporation of this fluid affords the pure white ſalt; and this, when diſtilled with the addition of vitriolic acid, affords the acid of fat, which comes over into the receiver, while the lime and vitriolic acid remain in the retort, in the form of ſelenite.

Characters of the acid of fat.

The general characters of the acid of fat are the following:—It is liquid, fuming, and of a penetrating ſmell; decompoſable by fire, which turns it yellow, and extricates or produces fixed air. Blue colours are ſtrongly reddened by it. Water diſſolves it in all proportions. With lime, and alſo with the fixed alkalis, it forms cryſtallizable ſalts, which are not decompoſed by heat. Siliceous earth appears to be

ſoluble

foluble in, or corroded by, this acid; and it acts on feveral of the metals.

Method of obtaining fpermaceti.

Spermaceti is a peculiar fubftance, of the nature of fat oil, which is found in the head of a fpecies of whale. One of thefe fifhes affords fome tons of brains, which are firft grofsly freed from the oil, by draining and preffing; and afterwards more perfectly purified, by fteeping them in a lye of alkaline falt and quick-lime, which converts the remains of the oily matter into foap. The brains being then wafhed with water, appear of a filver whitenefs; and nothing more is then required to complete the preparation, than to cut them in pieces with wooden knives, and fpread them abroad to dry. Good fpermaceti is in fine white flakes, gloffy, and femi-tranfparent; rather unctuous to the touch, though dry, and in fome meafure friable. Its fmell is faintifh, though not difagreeable; and it has fcarcely any tafte, on account of its being either nearly or totally infoluble in the faliva; expofure to the air renders it yellowifh and rancid in procefs of time; and that the more readily, in proportion as the original purification has been lefs complete. It may however be rendered white and fweet again, by fteeping it afrefh in cauftic alkali, and wafhing it in water.

Its character:

—and habitudes.

It is fcarcely, if at all, more combuftible than tallow; and is a much better material for candles, becaufe lefs fufible and greafy By diftillation it totally rifes, leaving no coal behind; but its component parts do not rife together. Four ounces of this fubftance afforded three ounces and a half of a

PARTS OF ANIMALS.

clear yellowiſh butyraceous oil, reſembling oil of wax in ſmell, and coagulate in the cold, like that ſubſtance; a drachm and a half of the product conſiſted of phlegm, and the reſt was waſted or diſſipated in the proceſs *.

Habitudes of ſpermaceti with various ſubſtances.

Water has no other effect upon ſpermaceti, when boiled with it, than to ſeparate a ſmall quantity of mucilaginous, or perhaps ſaponaceous matter, which is probably an impurity. Oils diſſolve it, by the aſſiſtance of heat; hot ardent ſpirit likewiſe diſſolves it, but lets the greateſt part fall upon cooling; ether diſſolves it very readily; ſulphur combines with this ſubſtance, in the ſame manner as it does with fat oils; the nitrous and marine acids have no action on it; concentrated vitriolic acid diſſolves it, but lets it fall again by heat.

Conjecture reſpecting its ſingular properties. Page 421—423. 499.

It has been conjectured that this ſingular ſubſtance bears the ſame relation to fat oils as camphor does to the eſſential oils. Wax appears to have the ſame relation to fixed oils, as reſin has to the eſſential; that is to ſay, both have been rendered concrete by the abſorption of vital air. But ſpermaceti and camphor ſeem to differ in ſome other leading particular; probably in the abſence of acid, or of any baſis which can eaſily be acidified by the action of nitrous or other acids. Much information would no doubt be derived from a careful examination of the products which theſe ſeveral ſubſtances afford by combuſtion.

* Neumann's Chemiſtry, by Lewis, ii. 422. Fourcroy, iv. 447, ſays that ſpermaceti forms a ſoap with cauſtic alkali; which is contrary to the poſitive aſſertion of Neumann, from whom the foregoing part of the text is taken.

The

Bones.

The bones of men and quadrupeds owe their great firmnefs and folidity to a confiderable portion of the phofphoric falt of lime which they contain. When thefe are rafped fmall, and boiled in water, they afford gelatinous matter, and a portion of fat or oil, which occupied their interftices. By deftructive diftillation they afford alkaline phlegm, a fetid oil, and much volatile alkali; leaving a coal not eafily burned. In an open fire, bones are inflamed by virtue of their oil, and emit an offenfive empyreumatic fmell. The white, friable, and incombuftible refidue, confifts chiefly of lime and phofphoric acid in combination. It affords a fmall quantity of mild mineral alkali by wafhing with water. This white matter is decompofable by fufion, with mild fixed alkalis, which unite with the phofphoric acid, at the fame time that the fixed air converts the lime into chalk. Acids likewife difengage the phofphoric acid, by uniting with the lime. The nitrous or the vitriolic acids are moft commonly ufed in this procefs.

White refidue.

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CHAP. V.

CONCERNING THE BILE, THE GASTRIC JUICE, AND THE ACID OBTAINED FROM ANTS.

ANIMAL FLUIDS.

THE fluids which remain to be confidered, as compofing part of animals, are the bile, the gaftric juice, and fuch acids as are obtained by treatment of animal matters.

Characters of the bile or gall.

The bile or gall is a fluid of a yellowifh green colour, exceffively bitter, and of a faint naufeous fmell. It is feparated from the blood in a glandular vifcus, well known by the denomination of the liver, and in moft animals is collected in a veffel called the gall bladder. The gall of oxen is that which chemifts have more particularly examined. Its confiftence is almoft gelatinous; by agitation it forms a froth fimilar to that of a folution of foap. Water diffolves it in all proportions; and this folution produces the fame effect as a folution of foap in fcouring cloths. All the acids decompofe it, and produce a coagulum, which feparates from the watery folution, at the fame time that the acid becomes neutralized by a portion of mineral alkali which unites with it. The coagulum, which may be feparated by the filter, is thick, vifcid, very bitter, and very inflammable. It appears fo far of a refinous nature, as to be totally foluble in ardent fpirit: hence it follows that the bile confifts principally of a foap compofed of this matter, and the mineral alkali. It alfo contains a quantity of ferum, which

which caufes it to coagulate by heat, or by the action of ardent fpirit, and difpofes it to putrefy. Ardent fpirit takes up the faponaceous matter, and leaves the ferum behind.

Deftructive diftillation of the bile.

Deftructive diftillation feparates firft an aqueous fluid, neither acid nor alkaline, but difpofed to putrefy. Nothing elfe paffes over upon the water-bath. The refidue is of a dark colour, very tenacious, like pitch, and totally foluble in water. If the diftillation be continued with caution, on account of the fwelling of the matter, the products are a yellowifh alkaline phlegm, empyreumatic oil, much volatile alkali, and the elaftic products confift of fixed and inflammable air. A confiderable coal remains, which contains mineral alkali, an earth, which is probably a combination of phofphoric acid and lime, and a fmall portion of iron.

Biliary concretions.

The nature of the biliary concretions which are formed in the gall bladder, has not yet been completely afcertained. Thefe are found fometimes of an irregular texture, and a brown, black, yellowifh, or greenifh colour; others confift of tranfparent cryftalline laminæ, fometimes radiated from the centre to the circumference. * Two ounces of biliary calculus, of a grey colour without, and brownifh green within, were diffolved in twelve times their weight of pure ardent fpirit, by the affiftance of a moderate heat. The hot folution being filtered, foon depofited, by cooling, a large quantity of laminated white brilliant cryftals, refembling the concrete acid of borax. The

* Fourcroy, in the Annales de Chimie, iii. 245.

quantity

ANIMAL FLUIDS.

Examination of the biliary calculus.

quantity amounted to near one fixteenth of the whole calculus; and, upon examination, it poffeffed the following properties:—It was inflammable, and melted by a gentle heat in a fpoon, with a fmell like wax, and cooled into a brittle fubftance of a cryftallized fracture: a fudden heat volatilized the whole. Water had no action upon it when cold; but boiling water caufed it to melt, and float on the furface like an oil, which became concrete by cooling. Cauftic alkalis converted it into foap. Nitrous acid diffolved it quietly, and the addition of water feparated it unaltered. Ardent fpirit diffolved it by heat; but the greateft part was feparated by cooling. Thefe characters indicate that it is a fubftance of the fame nature as fpermaceti. The author * of this valuable difcovery has alfo found that the cryftallized gall ftones contain this matter ftill more abundantly; and that it exifted in confiderable quantity in an human liver which had been expofed to the air for feveral years, and had loft its volatile parts by putrefaction. The affiduous refearches of the fame philofopher into the animal œconomy, have detected the fame fubftance, in a faponaceous form, in bodies which had been many years buried under ground.

The gaftric fluid.

A confiderable number of chemifts have examined the properties of the fluid which appears to be the menftruum of digeftion in the ftomachs of animals. It is certain that in this procefs the aliments become converted into a foft or pulpy mafs, moft probably by the action of a folvent, affifted by their own tendency

* Fourcroy, in the Annales before cited, iii. 120.

to

spontaneous decomposition, at the temperature of e body of the animal. The gastric juice procured om the stomachs of animals which have been kept sting for a considerable time, appears to differ ac-ording to their respective natures. It is thought to ossess a solvent power upon animal and vegetable ibstances, without any preference of affinity; but is last circumstance is scarcely probable. A power-il antiseptic quality is reckoned among its attributes; at there are some reasons to think that in graminivo-ous animals it has the contrary effect. In these last, ore especially, it contains a disengaged acid, which ems to be the phosphoric. And upon the whole, it ppears that accurate and decisive experiments are still anting, to determine the nature of this compounded nd variable fluid, which is of such important use in e animal œconomy.

The gastric fluid.

Acid of ants.

Of the acids which are considered as belonging ore especially to the animal kingdom, we have ready attended to those afforded by milk, by fat, y the stone of the bladder, by silk worms, and by e calcination of blood with an alkali, in the prepa-ation of Prussian blue; it therefore remains only for s to give an account of the acid which is afforded by nts. These animals appear to contain a peculiar id, in a vessel placed near the hinder part of their odies *, which they eject when enraged; or moisten eir fangs with it, to render their bite more painful. he acid may be obtained by distillation of the ants

* Wiegleb's Chemistry, by Hopson, p. 191. On this acid, nsult the authors there referred to; and also Fontana, in the urnal de Physique for 1778, part ii.

with

ANIMAL FLUIDS.

Acid of ants.

with water, and ſubſequent preſſure of the reſidue; or the ants may be tied up in a bag, and twice infuſed in hot water; from which infuſion as much acid may be diſtilled off as can be had without burning the reſidue. It may be purified by ſaturating it with alkali, filtrating, and evaporating part of the liquor, and diſtilling it with half its weight of vitriolic acid: or, more conveniently, the rectified acid may be expoſed to the action of a freezing atmoſphere, which congeals its aqueous part. This acid has a conſiderable reſemblance to vinegar when it is diluted. It acts upon, and combines with, alkalis, ſoluble earths, and metals, and forms peculiar compounds; from which, as well as the order of its elective attractions, its title to be conſidered as a diſtinct or peculiar acid is eſtabliſhed.

Deſtructive diſtillation converts it, like the vegetable acids, into fixed air and inflammable air.

APPENDIX.

VARIOUS TABLES USEFUL TO CHEMISTS.

AN ACCOUNT OF THE TABLES.

ACCOUNT OF TABLES.

Table of comparative heats.

TABLE I. contains a ſeries of numbers, expreſſing the comparative heats of bodies. It is copied from Crawford's Experiments and Obſervations on Animal Heat, and the Inflammation of Combuſtible Bodies: London, 1788. The principles on which this Table is formed, have been explained in page 14 of our Work, and elſewhere. Nothing more need therefore be ſaid, than that the numbers are here reduced to one common ſtandard of compariſon, water being aſſumed

ACCOUNT OF TABLES.

aſſumed as unity. As theſe numbers are deduced from the thermometrical changes undergone by the ſeveral bodies in like ſituations, it is clear that they are of uſe to indicate thoſe changes, for they will be inverſely as the numbers themſelves.

Table of weights.

TABLE II. contains the weights of different countries, compared in French and Engliſh grains. The value of this Table is obvious, and its character may be ſeen at page 70.

Table of ſpecific gravities.

TABLE III. exhibits the ſpecific gravities of bodies. In compiling this, I had Briſſon's Table at the end of Lavoiſier's Traité Elementaire de Chimie, and Muſchenbroek's large Table in his Cours de Phyſique, before me. Some few ſpecific gravities are from other authors, or from experiment. It appeared uſeleſs to carry it to more than four places of figures, as the temperatures were not noted, and the various ſpecimens of the ſame ſubſtance often differ in the third figure. Theſe aſſertions may be thought to require proof: for which reaſon I ſhall obſerve, that by experiment I find that the fifth figure changes at every three degrees of Fahrenheit's thermometer; that lead, tin, and probably all other metals caſt out of the ſame fuſion, vary in their ſpecific gravities in the third figure, from circumſtances not yet determined, but moſt likely from the cooling, as is ſeen in the hardening of ſteel; that ſalts, and other artificial preparations, retain more or leſs of the ſolvent they were ſeparated from, according to the temperature at which it was effected; and that all parts of organized ſubſtances not only differ according to the place of their production, their age, and other circumſtances, but like-

likewife from their drynefs, moifture, and manner of prefervation.

ACCOUNT OF TABLES.

Table of fpecific gravities of aerial fluids.

TABLE IV. is taken from the feventh Table of M. Lavoifier's Traité Elementaire. I have in another place * mentioned the ftrong objections which may be urged againft the fuppofed or implied accuracy of thefe weights, taken to fo many places of figures. In that place, as the object of attention was of a controverfial nature, it was proper to fpeak far within compafs; but on the prefent occafion I muft obferve, that the moft accurate practical chemifts would confider a true determination of the fpecific gravities of aerial fluids to three, or even two places of figures, as a great and valuable acquifition; and though I regard this Table as the beft we poffefs, yet in every inftance I doubt the accuracy of the third decimal, and in moft of them the fecond. The column of Englifh grains is fubftituted inftead of the weight of a cubic foot French, which occupies that place in the original.

Table of expanfions of airs.

TABLE V. is taken from an excellent Paper of Morveau, in the firft volume of the Annales de Chimie. The experiments were made by M. Prieur du Vernois upon the quantity of about 15½ cubic inches French, under the preffure of about 27 French inches of mercury, which anfwer to near 28 Englifh. The manner in which this inveftigation was conducted, does great credit to both the philofophers who were concerned in it; and the Effay itfelf, of which this Table is the refult, is highly deferving of the attention of thofe

* Preface to the fecond edition of Kirwan's Effay on Phlogifton, p. x.

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ſtudents who wiſh to know the precautions required in theſe delicate experiments, as well as of the ſtrict enquirer who may be deſirous of knowing how far he may depend on the Table itſelf.

Tables of elective attractions.

TABLES VI. to XI. contain in ſubſtance the two Tables of Attractiones Electivæ Simplices which are placed at the end of Bergman's Treatiſe on Elective Attractions, inſerted in the third volume of his Opuſcula, and of which we have had a ſeparate tranſlation into Engliſh. They have been ſince copied into a variety of works, and in moſt with amendments. I have not however ventured to make any alteration, except ſuch as tended to facilitate the inſertion of them in the regular pages of the book, inſtead of adopting the much leſs convenient mode of printing on a large ſheet to be folded out. Hence it is the arrangement of the columns only which is altered, and repetitions avoided; except that in Table VIII. there is a notice that the perlate acid, vital air, the matter of heat, and ſiderite, are left out; the reaſons for which need not be repeated here. Two inducements rendered it moſt eligible to retain the Tables, in other reſpects, the ſame as Bergman left them. The one was, that they might continue to be Bergman's Tables; and the other was, that, if I had been prepared for the arduous taſk of compoſing new Tables, it would have been incumbent on me to have fully ſtated my reaſons for the arrangements I might have adopted; which would have been incompatible with the limits of an Elementary Treatiſe.

With regard to theſe Tables, after earneſtly recommending the ſtudent to peruſe the work from which

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Elective attractions.

which they are extracted, it may be obferved, that the fubftances at the heads of the columns are confidered as fimple, with regard to the facts enumerated in thefe fketches, and fo likewife are the fubftances inferted in the columns. The order of pofition denotes that the higher any fubftance ftands in any column, the ftronger is its elective attraction to the fubftance at the head of that column. The under part of each Table exhibits the attractions in the dry way, and muft be confidered as entirely diftinct from the upper part. The horizontal lines between the fubftances in the columns denote that their pofitions, or comparative powers of attraction, are well determined; and, whenever thefe lines are wanting, the pofitions are more or lefs conjectural. Hence it may be feen how much remained to be done at the time the great Bergman conftructed thefe Tables.

TABLE XII. exhibits an approximation towards expreffing the powers of elective attraction between bodies generally applied. It is evident that the Tables of fimple elective attraction exprefs only the order in which the feveral enumerated fubftances furpafs each other in power to adhere to the common fubftance at the head of each column; and do not by any means fhew what will happen when a compound of two principles is applied to another compound alfo containing two principles, as in the cafes called double elective attraction. We cannot, in fact, decide in circumftances of this nature, unlefs we are previoufly acquainted with the fum of the two attractions which tend to preferve the original combinations, and are on that account very expreffively

ACCOUNT OF TABLES.

denominated by Mr. Kirwan quiescent attractions; and also with the sum of the other two attractions which tend to form new combinations, and are by the same chemist called the divellent attractions. Thus, for example, if vitriolated tartar, or the compound of vegetable alkali and vitriolic acid, be presented to the marine salt of lime, we cannot foretel the consequence from any simple Tables, because these will not shew whether the sum of the powers which tend to preserve the union of the alkali and vitriolic acid, and also of the lime and marine acid, be in fact greater or less than those by which the alkali tends to combine with the marine, and the lime with the vitriolic acid, and form the new compound of salt of sylvius and selenite. Hence we see the great advantage which the science of chemistry would derive from an extensive numerical Table founded on experiments of the nature of that now before us. For, in the present instance, we find from the Table, that the vegetable alkali and vitriolic acid adhere with a power expressed by the number 62; while the lime and marine acid adhere with a power denoted by 20. These are the quiescent affinities, and their sum is 82. On the other hand, by the same Table, we find that the attraction between vitriolic acid and lime is 54; and between vegetable alkali and marine acid 32. These are the divellent affinities, and their sum is 86. The latter must therefore prevail; that is, the combinations will be changed by the vitriolic acid melting with the lime, and forming selenite; while the marine acid combines with the vegetable alkali, and forms salt of sylvius.

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Table of ingredients in earths and ftones.

TABLE XIII. fhews the proportion of ingredients in earths and ftones. It is taken from Kirwan's Mineralogy. The extenfive and indefatigable refearches of this author into all the fources of chemical information, and the numerous additions he has himfelf made to the fcience, have enabled him to render this Table more perfect than any which is elfewhere to be met with. Much however remains ftill to be done, in every part of it, before we can depend on its accuracy throughout; and we hope the author will add the labour of perfecting it, to the other advantages which the fcientific world has derived from his exertions.

TABLE I. The Comparative Heats of different Bodies.

Inflammable air	21.4000
Dephlogiſticated air	4.7490
Atmoſpherical air	1.7900
Aqueous vapour	1.5500
Fixed air	1.0454
Arterial blood	1.0300
Water	1.0000
Freſh milk of a cow	.9999
Venous blood	.8928
Phlogiſticated air	.7936
Hide of an ox, with the hair	.7870
Lungs of a ſheep	.7690
Lean of the beef of an ox	.7400
Alcohol	.6021
Rice	.5060
Horſe beans	.5020
Spermaceti oil	.5000
Duſt of the pine tree	.5000
Peas	.4920
Wheat	.4770
Barley	.4210
Oats	.4160
Vitriolic acid	.4290
Pitcoal	.2777
Charcoal	.2631
Chalk	.2564
Ruſt of Iron	.2500
Waſhed diaphoretic antimony	.2272
Calx of copper, nearly freed from air	.2272
Quicklime	.2229
Cinders	.1923
Aſhes of cinders	.1855
Ruſt of iron, nearly freed from air	.1666
Waſhed diaphoretic antimony, nearly freed from air	.1666
Aſhes of the elm-tree	.1402
Calx of zinc, nearly freed from air	.1369
Iron	.1269
Braſs	.1123
Copper	.1111
White calx of tin, nearly freed from air	.0990
Regulus of zinc	.0943
Aſhes of charcoal	.0909
Tin	.0704
Yellow calx of lead, nearly freed from air	.0680
Regulus of antimony	.0645
Lead	.0352

TABLE II. The Weights of different Countries.

Place and Denomination of Weight.	Marc	oz.	gros.	grains.	F. grains.	E. grains.
Berlin. The marc of 16 loths — —		7	5	16	4408	3616.3
Berne. Goldſmiths weight of 8 ounces ——	1	—	½	4	4648	3813.2
Berne. Pound of 16 ounces, for merchandiſe —	2	1	½	6	9834	8067.7
The common pound varies very conſiderably in other towns of the Canton.						
Berne. Apothecaries weight of 8 ounces —	—	7	5½	26	4454	3654.
Bonn. —— —— ——	—	7	5	6¾	4308¾	3608.6
Bruſſels. The marc, or original troyes weight —	1	—	—	21	4629	3797.6
Cologn. The marc of 16 loths —— —	—	7	5	11	4403	3612.2
Conſtantinople. The cheki, or 100 drachms —	1	2	3	28	6004	4925.6
Copenhagen. Goldſmiths weight, commonly ſuppoſed equal to the marc of Cologn —	—	7	5½	10⅓	4438⅓	3641.2
Copenhagen. Merchants weight of 16 loths –	1	—	1	22½	4702½	3857.9
Dantzick. Weight commonly ſuppoſed equal to the marc of Cologn — —	—	7	5	3½	4395½	3606.
Florence. The pound (anciently uſed by the Romans)	1	3	½	20	6392	5244.
Genoa. The peſo ſottile — ——	1	2	2½	30	5970	4897.7
Genoa. The peſo groſſo — —	1	2	3	5	5981	4906.7
Hamburgh. Weight; commonly ſuppoſed equal to the Cologn marc — —	—	7	5	7¾	4399¾	3609.4
Hamburgh. Another weight — ——	—	7	7	23	4559	3740.2
Liege. The Bruſſels marc uſed; but the wt. proved	1	—	—	24	4632	3800.1
Liſbon. The marc, or half pound ——	—	7	3½	34	4318	3542.4
London. The pound troy — —	1	4	1½	1	7021	5760.
London. The pound avoirdupoiſe ——	1	6	6½	6	8538	7004.5
Lucca. The pound —— ——	1	3	—	23¼	6359¼	5217.
Madrid. The marc royal of Caſtile —	—	7	4	8	4328	3550.7
Malta. The pound —— ——	1	2	2½	21	5961	4890.4
Manheim. (The Cologn marc) ——	—	7	5	10¼	4402¼	3611.5
Milan. The marc — — —	—	7	5	33	4425	3630.2
Milan. The libra groſſa — --	3	—	7½	—	14364	11784.
Munich (The Cologn marc) — —	—	7	5	11½	4403½	3612.3
Naples. The pound of 12 ounces — —	1	2	3½	27	6039	4954.3
Ratiſbon. The weight for gold; of 128 crowns	1	6	—	24	8088	6635.3
Ratiſbon. The weight for ducats; of 64 ducats	—	7	2	32	4208	3452.3
Ratiſbon. The marc of 8 ounces ——	1	—	—	24	4632	3800.1
Ratiſbon. The pound of 16 ounces —	2	2	4½	6	10698	8776.5
Rome. The pound of 12 ounces ——	1	3	½	14	6386	5239.
Stockholm. The pound of 2 marcs ——	1	5	7	8	8000	6563.1
Stuttgard. (The Cologn marc) — —	—	7	5	11¾	4403¾	3612.6
Turin. The marc of 8 ounces — ——	1	—	—	22¼	4630¼	3799.
At Turin they have alſo a pound of 12 of the above ounces. But, in their apothecaries pound of 12 ounces, the ounce is one ſixth lighter.						
Warſaw. The pound —— ——	1	5	2	12	7644	6271.
Venice. The libra groſſa of 12 ounces ——	1	7	4½	25½	8989½	7374.5
Venice. The peſo ſottile of 12 ounces ——	1	1	6½	24	5676	4656.5
In the towns dependant on Venice, the pound differs conſiderably in each.						
Vienna. The marc of commerce ——	1	1	1	16	5272	4325.
Vienna. The marc of money — —	1	1	1	26	5282	4333.3
France. The grain —— ——	—	—	—	—	1.	1.21895
England. The grain —— ——	—	—	—	—	0,82039	1.

TABLE III. The Specific Gravities of Bodies.

Pure gold caſt	19258
——— hammered	19362
Standard gold caſt	17486
——— hammered	17589
Pure ſilver caſt	10474
——— hammered	10511
Standard ſilver in coin	10391
Crude platina in grains	15602
Platina purified and fuſed	19500
——— hammered	20337
——— drawn into wire	21042
——— laminated	22069
Mercury	13568
Lead fuſed	11352
Copper fuſed	7788
——— drawn into wire	8878
Braſs caſt	8396
——— in wire	8544
Iron caſt	7207
——— bar	7788
Steel, ſoft and not hammered	7840
——— hardened	7816
Tin, Engliſh, fuſed	7291
——— hammered	7299
Malacca tin fuſed	7296
——— hammered	7306
Biſmuth	9823
Nickel	8660
Arſenic, the regulus	5763
Cobalt	7812
Zinc	7191
Antimony	6702
Mangancſe	6850
Wolfram	17600
Diamond	3521
Ruby	4283
——— ſpinell	3760
Topaz, oriental	4011
——— Brazilian	3536
——— Saxon	3564
Sapphire, oriental	3994
Emerald	2775
Adamantine ſpar	4180
Jargon of Ceylon	4615
Rock cryſtal from Madagaſcar	2653
Quartz	2654
Agate	2590

Onyx	2637
Muſcovy talc	2792
Common ſlate	2672
Calcareous ſpar	2715
Alabaſter	2730
White marble	2716
Lime ſtones from	1386
——— to	2390
Ponderous ſpar	4474
Fluor ſpar	3180
Pumice ſtone	914
Green glaſs	2620
Engliſh crown glaſs	2520
White flint glaſs, Engliſh	3290
Another piece	3216
White flint glaſs, for achromatic uſes	3437
White glaſs, French	2892
Glaſs of S. Gobin	2488
Brimſtone	1990
Phoſphorus	1714
Yellow amber	1078
Diſtilled water	1000
Sea water	1026
Common ſpirit of wine	837
Spirit of wine, the pureſt which can be had by mere diſtillation	820
Vitriolic ether	739
Nitrous	909
Marine	730
Acetous	866
Concentrated vitriolic acid	2125
——— nitrous acid	1580
——— marine acid	1194
Fluor acid	1500
Oil of olives	915
— of ſweet almonds	917
Linſeed oil	940
Naptha	708
Gum elaſtic	933
Camphor	989
Yellow wax	965
White Do.	969
Spermaceti	943
Tallow	942
Heart of oak	1170
Cork	240
Egg new laid	1081

TABLE IV. The Specific Gravities of Aerial Subſtances; the Barometer ſtanding at 30 Inches, and the Thermometer at + 55°.*

Names of Aerial Subſtances.	Weight of one cubic Inch. French.	Engliſh.	From the Experiments of
	French grains.	Engliſh grains.	
Atmoſpheric air	0.46005	0.45689	M. Lavoiſier.
Phlogiſticated air	0.44444	0.44139	The ſame.
Vital air	0.50694	0.50346	The ſame.
Inflammable air	0.03539	0.03515	The ſame.
Fixed air	0.68985	0.68511	The ſame.
Nitrous air	0.54690	0.54314	M. Kirwan.
Alkaline air	0.27488	0.27299	The ſame.
Vitriolic air	1.03820	1.03109	The ſame.

* Strictly the numbers are 29.84 inches and 54.5 degrees; anſwering to 28 French inches, and 10 deg. of Reaumur.

TABLE V. The Expanſions of Aerial Subſtances by Heat, from the Freezing to the Boiling Points of Water. For every Interval of 20° of Reaumur's, or 45° of Fahrenheit's Thermometer.

Names.	From 32° to 77°	From 77° to 122°	From 122° to 167°	From 167° to 212°	Total From 32° to 212°
Common air	$\frac{1}{12.67}$	$\frac{1}{3.61}$	$\frac{1}{2.49}$	[$\frac{1}{3.[illegible]}$]	$\frac{1}{1.067}$
Vital air	$\frac{1}{22.12}$	$\frac{1}{4.92}$	$\frac{1}{1.53}$	[$3+\frac{1}{1.93}$]	$4+\frac{1}{2.09}$
Phlogiſt. air	$\frac{1}{29.41}$	$\frac{1}{7.41}$	$\frac{1}{1.82}$	[$5+\frac{1}{37.2}$]	$5+\frac{1}{1.062}$
Inflam. air	$\frac{1}{11.01}$	$\frac{1}{7.92}$	[$\frac{1}{7.83}$]	[$\frac{1}{13.82}$]	$\frac{1}{2.[illegible]3}$
Nitrous air	$\frac{1}{17.33}$	$\frac{1}{9.00}$	$\frac{1}{3.739}$	[$\frac{1}{6.88}$]	$\frac{1}{1.63}$
Fixed air	$\frac{1}{9.049}$	$\frac{1}{3.099}$	$\frac{1}{2.31}$	[$\frac{1}{3.89}$]	$1+\frac{1}{107.3}$
Alkaline air	$\frac{1}{3.38}$	$\frac{1}{1.73}$	$1+\frac{1}{1.35}$	[$3+\frac{1}{4.69}$]	$5+\frac{1}{3.248}$

*** The numbers between brackets are uncertain.

TABLE VI. Simple Elective Attractions.
ACIDS.

Vitriolic Acid.	Nitrous Acid.	Marine Acid.	Fixed Air.	Acid of Borax.	Acid of Amber.	Acetous Acid distilled.
Barytes	Veg. alkali ?	Veg. alkali ?	Barytes	Lime	Barytes	Barytes
Veg. alkali	Min. alkali ?	Min. alkali ?	Lime	Barytes	Lime	Veg. alkali
Min. alkali	Barytes ?	Barytes ?	Veg. alkali	Magnefia	Magnefia	Min. alkali
Lime	Lime	Lime	Min. alkali	Veg. alkali	Veg. alkali	Vol. alkali
Magnefia	Magnefia	Magnefia	Magnefia	Min. alkali	Min. alkali	Lime
Vol. alkali	Vol. alkali	Vol. alkali	Vol. alkali	Vol. alkali	Vol. alkali	Magnefia
Clay	Clay	Clay	Clay	Clay	Clay	Clay
Metallic calces Water Ardent fpirit Phlogifton	Metallic calces Water Ardent fpirit Phlogifton	Metallic calces Water Ardent fpirit Phlogifton	Metallic calces Water Ardent fpirit	Metallic calces Water Ardent fpirit Phlogifton	Metallic calces Water Ardent fpirit Phlogifton	Metallic calces Water Ardent fpirit Phlogifton
N. B. The fulphureous or volatile vitriolic acid follows the fame order in the humid way.	N. B. The fuming nitrous acid follows the fame order in the humid way.	N. B. The dephlogifticated or aerated marine acid follows the fame order in the humid way.	In the Dry Way.	N. B. The fame order is followed by the acids of fugar or forrel; tartar; and lemon.	The order in which the metallic calces precipitate each other in acids, is the reverfe of that in the column of phlogifton, in Table IX. Confult page 132.	
Phlogifton	Phlogifton	Phlogifton	Prussian Acid.			
Veg. alkali Min. alkali Barytes Lime Magnefia Metallic calces	Barytes Veg. alkali Min. alkali Lime Magnefia Metallic calces	Barytes Veg. alkali Min. alkali Lime Magnefia Metallic calces	In the Humid Way. Veg. alkali Min. alkali Vol. alkali	Lime Barytes Magnefia Veg. alkali Min. alkali Metallic calces	Barytes Lime Magnefia Veg. alkali Min. alkali Metallic calces	Barytes Veg. alkali Min. alkali Lime Magnefia Metallic calces
Vol. alkali	Vol. alkali	Vol. alkali	Lime Barytes Magnefia	Vol. alkali	Vol. alkali	Vol. alkali
Clay	Clay	Clay	Clay	Clay	Clay	Clay
		N. B. Aqua regia follows the fame order both in the humid and dry way.	Metallic calces Water	N. B. The fame order both in the humid and dry way is followed by the acids of fpar; of arfenic; of benzoin; of fugar of milk; of fat; and of phofphorus: except that phlogifton occupies the firft place in the dry way with the arfenical acid.		N. B. The fame order both in the humid and dry way is followed by the acids of milk and of ants.

TABLE VII. Simple Elective Attractions.

ALKALIS AND EARTHS.

IN THE HUMID WAY.

VEG. ALKALI	MIN. ALKALI	CLAY.	LIME.	BARYTES.	MAGNESIA.
Vitriolic acid		Vitriolic acid	A. of ſugar	Vitriolic acid	Acid of ſugar
Nitrous acid	This alkali agrees with the vegetable in the order of its attractions, both in the humid and the dry way.	Nitrous a.	Vitriolic a.	A. of ſugar	Phoſphor. a.
Marine acid		Marine a.	A. of tartar	A. of amber	Vitriolic acid
Acid of fat		A. of ſugar	A. of amber	A. of ſpar	A. of ſpar
Acid of ſpar		Arſenical a.	Phoſphor. a.	Phoſphor. a.	A. of fat
Phoſphor. acid		Sparry a.	A. of ſ. of milk	A. of ſ. of milk	A. of arſenic
A. of ſugar		A. of fat	Nitrous acid	Nitrous acid	A. of ſ. of milk
A. of tartar		A. of tartar	Marine acid	Marine acid	A. of amber
A. of arſenic		A. of amber	A. of fat	A. of fat	Nitrous acid
A. of amber		A. of ſ. of milk	A. of ſpar	A. of lemon	Marine acid
A. of lemon		A. of lemon	A. of arſenic	A. of tartar	A. of tartar
A. of ants	VOL. ALKALI.	Phoſphor. a.	A. of ants	A. of arſenic	A. of lemon
A. of milk		A. of ants	A. of milk	A. of ants	A. of ants
A. of benzoin	This alkali agrees with the vegetable in the order of its attractions, both in the humid and dry way: but mere heat expels it from the acids of phoſphorus, borax, and arſenic.	A. of milk	A. of lemons	A. of milk	A. of milk
Acetous acid		A. of benzoin	A. of benzoin	A. of benzoin	A. of benzoin
A. of ſ. of milk		Acetous acid	Acetous acid	Acetous acid	Acetous acid
Acid of borax		A. of borax	Acid of borax	Acid of borax	A. of borax
Vol. vitr. a.		Vol. vitr. a.	Vol. vitr. a.	Vol. vitr. a.	Vol. vitr. a.
Fuming nitr. a		Fum. nitr. a.	Fum. nitr. a.	Fum. nitr. a.	Fum. nitr. a.
Fixed air		Fixed air	Fixed air	Fixed air	Fixed air
Pruſſian acid		Pruſſian acid	Pruſſian a.	Pruſſian a.	Pruſſian a.
Water			Water	Water	
Fat oils			Fat oils	Fat oils	
Sulphur			Sulphur	Sulphur	Sulphur
Met. calces					

IN THE DRY WAY.

Phoſphor. acid	SILEX.	Phoſphor. acid	Phoſphor. acid	Phoſphor. acid	Phoſphor. acid
A. of borax		A. of borax	A. of borax	A. of borax	A. of borax
A. of arſenic	In the HUMID WAY.	A. of arſenic	A. of arſenic	A. of arſenic	A. of arſenic
Vitriolic acid		Vitriolic acid	Vitriolic acid	Vitriolic acid	Vitriolic acid
Nitrous acid	A. of ſpar	Nitrous acid	A. of amber	A. of amber	A. of ſpar
Marine acid	Veg. alkali	Marine acid	Nitrous acid	Acid of ſpar	A. of fat
A. of fat		A. of ſpar	Marine acid	Nitrous acid	A. of amber
A. of ſpar		A. of fat	A. of fat	Marine acid	Nitrous acid
A. of amber	In the DRY WAY.	A. of amber	A. of ſpar	A. of fat	Marine acid
A. of ants	Fixed alkali	A. of ants	A. of ants	A. of ants	A. of ants
A. of milk	Phoſphor. acid	A. of milk	A. of milk	A. of milk	A. of milk
A. of benzoin	Calx of lead	A. of benzoin	A. of benzoin	A. of benzoin	A. of benzoin
Acetous acid		Acetous acid	Acetous acid	Acetous acid	Acetous acid
Barytes		Fixed alkali	Fixed alkali	Fixed alkali	Fixed alkali
Lime		Sulphur	Sulphur	Sulphur	Sulphur
Magneſia		Calx of lead	Calx of lead	Calx of lead	Calx of lead
Clay					
Silex					
Sulphur					

TABLE VIII. Simple Elective Attractions.

COMBUSTIBLE SUBSTANCES AND WATER.

IN THE HUMID WAY.

Water.	Sulphur.	Saline Liver of Sulphur.	Ardent Spirit	Ether.
Veg. alkali	Calx of lead	Calx of gold	Water	Ardent ſpirit
Min. alkali	C. of tin	C. of ſilver	Ether	Eſſential oils
Vol. alkali	C. of ſilver	C. of mercury	Eſſential oils	Expreſſed oils
Ardent ſpirit	C. of mercury	C. of arſenic	Volatile alkali	Water
Mild vol. alk.	C. of arſenic	C. of antimony	Fixed alkali	Sulphur
Glauber's ſalt	C. of antimony	C. of biſmuth	Saline hepar	
Ether	C. of iron	C. of copper	Sulphur	
	Veg. alkali	C. of tin		
	Vol. alkali	C. of lead		
	Barytes	C. of nickel		
	Lime	C. of cobalt		
	Magneſia	C. of manganeſe		
Vitriolic acid		C. of iron		
Vitriolated tartar	Fat oils			
Alum	Eſſential oils	Ardent ſpirit		
Martial vitriol	Ether	Water		
Corroſ. ſublimate	Ardent ſpirit			

Expressed Oil	Essential Oil
Ether	Ether
Eſſential oils	Ardent ſpirit
Fixed alkalis	Fat oils
Vol. alkali	Fixed alkalis
Sulphur	Sulphur

IN THE DRY WAY.

Fixed alkali	Manganeſe
Iron	Iron
Copper	Copper
Tin	Tin
Lead	Lead
Silver	Silver
Cobalt	Gold
Nickel	Antimony
Biſmuth	Cobalt
Antimony	Nickel
Mercury	Biſmuth
Arſenic	Mercury
	Arſenic

Four of the columns in the original tables of Bergman are omitted in theſe, viz.

The perlate acid; for which ſee page 209.

Vital air, which is ſuppoſed to have an affinity to phlogiſton only.

The matter of heat; for which ſee pages 6. 21.

The ſemimetal ſiderite; for which ſee page 313.

TABLE IX. Simple Elective Attractions.

PHLOGISTON AND METALS.

IN THE HUMID WAY.

Phlogiston	Calx of Gold	C. of Silver	C. of Platina	C. of Mercury.	C. of Lead.
Nitrous acid	Ether	Marine acid	Ether	Acid of fat	Vitriolic acid
Vitriolic acid	Marine acid	Acid of fat	Marine acid	Marine acid	Acid of fat
Dephl. marine a.	Aqua regia	Acid of sugar	Aqua regia	Acid of sugar	A. of s. of milk
Arsenical acid	Nitrous acid	Vitriolic acid	Nitrous acid	Acid of amber	A. of sugar
Phosphor. acid	Vitriolic acid	A. of s. of milk	Vitriolic acid	Arsenical acid	Arsenical acid
	Arsenical acid	Phosphor. acid	Arsenical acid	Phosphor. acid	Acid of tartar
C. platina	Sparry acid	Nitrous acid	Sparry acid	Vitriolic acid	Phosphor. acid
C. gold	Acid of tartar	Arsenical acid	Acid of tartar	A. of s. of milk	Marine acid
C. silver	Phosphor. acid	Sparry acid	Phosphor. acid	Acid of tartar	Nitrous acid
C. mercury	Acid of fat	Acid of tartar	Acid of fat	Acid of lemon	Sparry acid
C. arsenic	Prussian acid	Acid of lemon	Acid of sugar	Nitrous acid	Acid of lemons
C. antimony		Acid of ants	Acid of lemons	Sparry acid	Acid of ants
C. bismuth		Acid of milk	Acid of ants	Acetous acid	Acid of milk
C. copper		Acetous acid	Acid of milk	Acid of borax	Acetous acid
C. tin		Acid of amber	Acetous acid	Prussian acid	Acid of borax
C. lead		Prussian acid	Acid of amber	Fixed air	Prussian acid
C. nickel		Fixed air			Fixed air
C. cobalt	Fixed alkali				Fixed alkali
C. manganese	Vol. alkali	Vol. alkali			
C. iron					
C. zinc					
Water					

N. B. In the antiphlogistic theory, the column intitled *Phlogiston* being taken in a reversed order, will express the elective attractions of *Vital air.*

IN THE DRY WAY.

	Gold.	Silver.	Platina.	Mercury.	Lead.
C. of platina	Mercury	Lead	Arsenic	Gold	Gold
C. gold	Copper	Copper	Gold	Silver	Silver
Acid of arsenic	Silver	Mercury	Copper	Platina	Copper
C. silver	Lead	Bismuth	Tin	Lead	Mercury
C. mercury	Bismuth	Tin	Bismuth	Tin	Bismuth
C. arsenic	Tin	Gold	Zinc	Zinc	Tin
C. antimony	Antimony	Antimony	Antimony	Bismuth	Antimony
C. bismuth	Iron	Iron	Nickel	Copper	Platina
C. copper	Platina	Manganese	Cobalt	Antimony	Arsenic
C. tin	Zinc	Zinc	Manganese	Arsenic	Zinc
C. lead	Nickel	Arsenic	Iron	Iron	Nickel
C. nickel	Arsenic	Nickel	Lead		Iron
C. cobalt	Cobalt	Platina	Silver		
C. manganese	Manganese		Mercury		
C. iron	Sa. liv. of sulph.	S. l. of sulph.	S. l. of sulph.	S. l. sulph.	S. l. sulphur
C. zinc		Sulphur		Sulphur	Sulphur

TABLE X. Simple Elective Attractions.

METALLIC SUBSTANCES.

IN THE HUMID WAY.

Calx of Copper.	Calx of Iron.	Calx of Tin.	Calx of Bismuth.	Calx of Nickel.	Calx of Arsenic.
Acid of ſugar	Acid of ſugar	Acid of fat	Acid of ſugar	Acid of ſugar	Marine acid
Acid of tartar	Acid of tartar	Acid of tartar	Acid of arſenic	Acid of ſorrel	Acid of ſugar
Marine acid	Vitriolic acid	Marine acid	Acid of tartar	Marine acid	Vitriolic acid
Vitriolic acid	A. of ſ. of milk	Vitriolic acid	Phoſphor. acid	Vitriolic acid	Nitrous acid
A. of ſ. of milk	Marine acid	Acid of ſugar	Vitriolic acid	Acid of tartar	Acid of fat
Nitrous acid	Nitrous acid	Arſenical acid	Acid of fat	Nitrous acid	Acid of tartar
Acid of fat	Acid of fat	Phoſphor. acid	Marine acid	Acid of fat	Phoſphor. acid
Arſenical acid	Phoſphor. acid	Nitrous acid	Nitrous acid	Phoſphor. acid	Acid of ſorrel
Phoſphor. acid	Arſenical acid	Acid of amber	Fluor acid	Fluor acid	Fluor acid
Acid of amber	Sparry acid	Sparry acid		A. of ſ. of milk	A. of ſ. of milk
Sparry acid	Acid of amber	A. of ſ. of milk		Acid of amber	Acid of amber
Acid of lemon	Acid of lemons	Acid of lemons		Acid of lemon	Acid of lemon
Acid of ants	Acid of ants	Acid of ants		Acid of ants	Acid of ants
Acid of milk	Acid of milk	Acid of milk		Acid of milk	Acid of milk
Acetous acid	Acetous acid	Acetous acid		Acetous acid	Arſenical acid
Acid of borax	Acid of borax	Acid of borax		Arſenical acid	Acetous acid
Pruſſian acid	Pruſſian acid	Pruſſian acid		Acid of borax	
Fixed air	Fixed air			Pruſſian acid	Pruſſian acid
Fixed alkali		Fixed alkali		Aerial acid	
Vol. alkali		Vol. alkali		Volatile alkali	Volatile alkali
Fat oils					Unctuous oils
					Water

IN THE DRY WAY.

Copper.	Iron.	Tin.	Bismuth.	Nickel.	Arsenic.
Gold	Nickel	Zinc	Lead	Iron	Nickel
Silver	Cobalt	Mercury	Silver	Cobalt	Cobalt
Arſenic	Manganeſe	Copper	Gold	Arſenic	Copper
Iron	Arſenic	Antimony	Mercury	Copper	Iron
Manganeſe	Copper	Gold	Antimony	Gold	Silver
Zinc	Gold	Silver	Tin	Tin	Tin
Antimony	Silver	Lead	Copper	Antimony	Lead
Platina	Tin	Iron	Platina	Platina	Gold
Tin	Antimony	Manganeſe	Nickel	Biſmuth	Platina
Lead	Platina	Nickel	Iron	Lead	Zinc
Nickel	Biſmuth	Arſenic	Zinc	Silver	Antimony
Biſmuth	Lead	Platina		Zinc	
Cobalt	Mercury	Biſmuth			
Mercury		Cobalt			
Sal. liv. of ſulph.	S. l. of ſulphur	S. l. of ſulph.	S. l. of ſulph.	S. l. of ſulph.	S. l. of ſulph.
Sulphur	Sulphur	Sulphur	Sulphur	Sulphur	Sulphur

TABLE XI. Simple Elective Attractions.

METALLIC SUBSTANCES.

IN THE HUMID WAY.

Calx of Cobalt.	Calx of Zinc.	Calx of Antimony.	Calx of Manganese.	Calx of Wolfram.
Acid of ſugar	Acid of ſugar	Acid of fat	Acid of ſugar	Lime
Acid of ſorrel	Vitriolic acid	Marine acid	Acid of ſorrel	Vegetable alkali
Marine acid	Marine acid	Acid of ſugar	Acid of lemon	Volatile alkali
Vitriolic acid	Acid of ſ. of milk	Vitriolic acid	Phoſphoric acid	
Acid of tartar	Nitrous acid	Nitrous acid	Acid of tartar	
Nitrous acid	Acid of fat	Acid of tartar	Fluor acid	
Acid of fat	Acid of ſorrel	Acid of ſorrel	Marine acid	In the Dry Way.
Phoſphoric acid	Acid of tartar	Acid of ſ. of milk	Vitriolic acid	Fixed alkali
Fluor acid	Phoſphoric acid	Phoſphoric acid	Nitrous acid	Lime
Acid of ſ. of milk	Acid of lemon	Acid of lemon	Acid of ſ. of milk	Calx of iron
Acid of amber	Acid of amber	Acid of amber	Acid of amber	Calx of manganeſe
Acid of lemon	Fluor acid	Fluor acid	Acid of fat	
Acid of ants	Arſenical acid	Arſenical acid	Arſenical acid	This column is additional. It is deduced from De Luyart's Analyſis.
Acid of milk	Acid of ants	Acid of ants	Acid of ants	
Acetous acid	Acid of milk	Acid of milk	Acid of milk	
Arſenical acid	Acetous acid	Acetous acid	Acetous acid	
Acid of borax	Acid of borax	Acid of borax		
Pruſſian acid	Pruſſian acid	Pruſſian acid	Pruſſian acid	
Aerial acid	Aerial acid	Aerial acid	Aerial acid	
Volatile alkali	Volatile alkali			

IN THE DRY WAY.

Cobalt.	Zinc.	Antimony.	Manganese.	Wolfram.
Iron	Copper	Iron	Copper	Iron
Nickel	Antimony	Copper	Iron	Silver
Arſenic	Tin	Tin	Gold	Tin
Copper	Mercury	Lead	Silver	Lead
Gold	Silver	Nickel	Tin	Antimony
Platina	Gold	Silver		Biſmuth
Tin	Cobalt	Biſmuth		Manganeſe
Antimony	Arſenic	Zinc		Gold
Zinc	Platina	Gold		Platina
	Biſmuth	Platina		
	Lead	Mercury		
	Nickel	Arſenic		
	Iron	Cobalt		
Saline liv. of ſulph.		Sal. liv. of ſulphur	Sal. liv. of ſulphur	
Sulphur		Sulphur		

TABLE XII. Numerical Expreffion of Attractions by M. Morveau.

	Vitriolic Acid.	Nitrous Acid.	Marine Acid.	Acetous Acid.	Aerial Acid or Fix. Air.
Ponderous earth	65	62	36	29	14
Vegetable alkali	62	58	32	26	9
Mineral alkali	58	50	28	25	8
Lime	54	44	20	19	12
Volatile alkali	46	38	14	20	4
Magnefia	50	40	16	17	6
Argil. earth	40	36	10	15	2

TABLE XIII. Of the Proportion of Ingredients in Earths and Stones.

Calcareous Genus.

100 Parts.	Calcar.	Argill.	Silex.	Mag.	Wat.	Iron.
Calcareous fpar -	55	- -	- -	—	11	— a
Gypfum - -	32	- -	- -	—	38	— b
Fluor - - -	57	- -	- -	—	—	— c
Tungften - -	50	- -	- -	—	—	— d
Compound fpar -	60	- -	- -	35	—	5 e
Cruetzenwald ftone	75	- -	- -	12	—	3 f
Calcareous marle -	50to75	20to30	20to30	—	—	— g
Margodes - -	50	32	15	—	—	2
Stellated fpar - -	66	- -	30	—	—	3
Calcareous grit or fand ftone	50	- -	- -	—	—	— h
Swine ftone - -	95	- -	- -	—	—	— i
Pyritaceous limeftone	75	14	- -	—	—	4 k
Martial tungften -	- -	- -	- -	—	—	50 l

a And 34 fixed air. —— *b* And 30 vitriolic acid. —— *c* 43 acid and water. —— *d* 50 acid and iron. —— *e* Both earths mild. —— *f* Ditto. —— *g* And water. —— *h* Or more; remainder, filex, argill. and iron. —— *i* And petrol.; remainder, argill. and iron. —— *k* And 7 quartz and fulphur, that is, 25 pyrites. —— *l* By the dry way only 30, and 50 tungften.

Barytic or Ponderous Genus.

100 Parts.	
Mild barytes	78 Earth, 20 fixed air, 2 barofelenite.
Barofelenite	84 Earth, 13 vitriolic acid, and 3 water.
Hepatic ftone	33 Barofelenite, 33 filex, 22 alum, 7 gypfum, 5 petroleum.

Muriatic or Magneſian Genus.

100 Parts.	Silex.	Calc.	Magneſia.	Argill	Water.	Iron.
Mild magneſia - - -	—	—	48	—	22	—*
Keffekil - - -	50	—	50	—	—	—
Steatites - - -	80	—	17	2	—	1
Argillaceous ſteatites -	72	—	17	11	—	—
Chalk of Briançon -	70	—	17	11	—	—†
Soap rock - -	70	—	17	13	—	—
Aſbeſtos - - -	63	11	20	4	—	2‡
Martial aſbeſtos - -	62	12	13,7	1,7	—	10,6
Suber montanum - -	59	11	24	2,4	—	3,6‖
Amianthus - -	64	6,9	18,6	3,3	—	1,2§
Serpentine - -	45	—	23	18	12	3
Talc, Muſcovy - -	50	—	45	5	—	—

Talc, Venetian - - a larger portion of argill, and ſmaller of magneſia.

Note, The magneſia and calcareous earths are in a mild ſtate, in all the above ſtones.

* At a medium, and 30 fixed air.——† And 2 of talc.——‡ At a medium.——‖ At a medium.——§ And 6 barytes.

Argillaceous Genus.

100 Parts.	Silex.	Argill	Calcareous	Magneſia.	Iron.	Water.
Pure clay, dry -	63	37*	——	——	—	—
Argillac. marl, dry -	46	27	25 †	——	—	—
Fullers earth -	53	18	5	3	4	17 ‡
Pouzzolana - -	57	20	6	——	20	—
Tripoli - -	90	7	——	——	3	—
Pure mica - -	38	28	——	20	14 ‖	—
Martial mica -	34,5	25,5	——	18	22	—
Roof ſlate or ſhiſtus	46	26	4 mild	8 mild	14	—
Flagſt. or argill. ſhiſt.	36	56	——	——	4	—
Horn-ſtone - -	37	22	2	16	23	—
Killas - - -	60	25	——	9	6	—
Toadſtone - -	63	14	7	——	16	—
Zeolyte - -	60	20	8	——	—	12 §
Pitch-ſtone -	65	16	——	——	5	14 ¶

Gronſten - - Horn-ſtone and mica, or horn-ſtone and ſhoerl.

Stellſten - - Mica, quartz and argill.

Binda - - Horn-ſtone, mica, ſhoerl, quartz, and pyrites.

Growan - - Argill, mica, and quartz.

* At a medium, when perfectly dry, 63 ſiliceous——† Mild at a medium. ‡ And marine acid at a medium.——‖ White calx of iron.——§ At a medium.——¶ And air.

Siliceous

Siliceous Genus.

100 Parts.	Silex.	Argill	Calcar.	Magn.	Iron.
Cryſtal - - -	93	6	1	—	—
Flint - - -	80	18	2	—	—
Petroſilex - -	72	22	6	—	—
Jaſper - - -	75	20	—	—	5
Chalcedonian - -	84	16	—	—	—
Ruby - - -	39	40	mild 9	—	10
Topaz - - -	39	46	ditto 8	—	6
Hyacinth - -	25	40	dit. 20	—	13
Emerald - - -	24	60	8	—	6
Sapphire - - -	35	58	5	—	2
Chryſopraſium - -	95	—	1,7	1,2	0,4 *a*
Lapis lazuli - -	—	—	—	—	— *b*
Felt ſpar - -	67	14	—	8	— *c*
Veſuvian garnet -	55	39	6	—	—
Garnet - - -	48	30	12	—	10
Martial garnet - -	43,6	27,6	10	—	19
Shoerl tranſparent -	48	40	5	1	5
Shoerl black - -	58	27	5	1	5
Bar ſhoerl - - -	61,6	6,6	21,6	5	1,6 *d*
Tourmaline - -	37	45	13	—	5 *e*
Baſaltes - - -	52	15	8	2	25
Rowley ragg - -	47,5	32,5	—	—	20
Comp. and cellular lava	47	30	5	—	18
Vitreous ditto - -	49	35	4	—	12
Another from Lapari -	69	22	—	—	9
Black agate of Iceland nearly as the above	—	—	—	—	—
Pumice ſtone - -	84 or 90	—	—	6 to 10	— *f*
Martial muriatic ſpar -	50	—	—	30 mild	20 *g*
Turkey ſtone - -	70	5	mild 25	—	— *h*
Ragg ſtone - -	70	5	dit. 20	—	5 *i*
Siliceous grit, with calcareous cement	62,5	—	do. 37,5	—	—
Siliceous ditto, with argillaceous cement -	77	20	—	—	3 *k*
Ditto, with ferruginous cement - -	80	5	—	—	15 *l*

a 0,6 copper, and ſparry acid.——*b* 80 martial fluor, 20 gypſum, as I believe.——*c* 11 ponderous.——*d* 5 water.——*e* At a medium. *f* Remainder calcareous.——*g* As I believe.——*h* As I believe. *i* As I believe.——*k* As I believe.——*l* As I believe.

Siliceous Genus continued.

Granite - -	Quartz, felt ſpar and mica. Quartz, felt ſpar and ſhoerl.
Stellſten - - Granitello - -	Quartz and mica.
Rapakivi - - Granitone - -	Felt ſpar and mica.
Murkſten - - Norka - - -	Quartz, garnet, and mica.
Porphyry - -	Jaſper, chert, lava, ſhoerl containing quartz, felt ſpar, ſhoerl, mica, or ſerpentine in a cryſtalline form.
Pudding ſtone - -	Jaſper, chert, ſiliceous grit, or lava, containing pebbles of an oval form.
Siliceous breccias -	The ſame ground and contents, but in angular forms.
Gneiſs - - -	Quartz, mica, ſteatites. Quartz, mica, ſerpentine. Quartz, mica, ſhoerl, ſteatites, or ſoap rock. Quartz, felt ſpar, mica, ſerpentine.
Amygdaloides - -	Jaſper, or chert, containing ſpar or ſerpentine.
Metallic rock of Born	Quartz, clay, and ſteatites, and felt ſpar ſometimes.
Variolite - -	Serpentine, containing various ſtones.

Proportion of Ingredients in Natural Salts.

Salts.	Acids	Alka.	Earth	Water.	
Tartar vitriolate -	31	63	—	6	
Glauber's ſalt -	14	22	—	64	
Vitriolic ammoniac	42	40	—	18	
Epſom - -	24	—	19	57	
Alum - -	24	—	18	58	
Vitriol of iron -	20	—	—	55	25 iron.
Ditto of copper -	30	—	—	43	27 copper.
Ditto of zinc -	22	—	—	58	20 zinc.
Nitre - -	30	63	—	7	
Cubic nitre - -	29	50	—	21	
Nitrous ammoniac	46	40	—	14	
Nitrous ſelenite -	33	—	32	35	
Ditto Epſom -	36	—	27	37	
Salt of Silvius -	30	63	—	7	
Common ſalt -	33	50	—	17	
Sal ammoniac -	52	40	—	8	
Marine ſelenite -	42	—	38	20	
Borax purified -	34	17	—	47	

I N D E X.

A.

B.

C.

D.

E.

F.

G.

H.

I.

K.

L.

M.

N.

O.

P.

Q.

R.

S.

T.

U, V.

Vegetables,