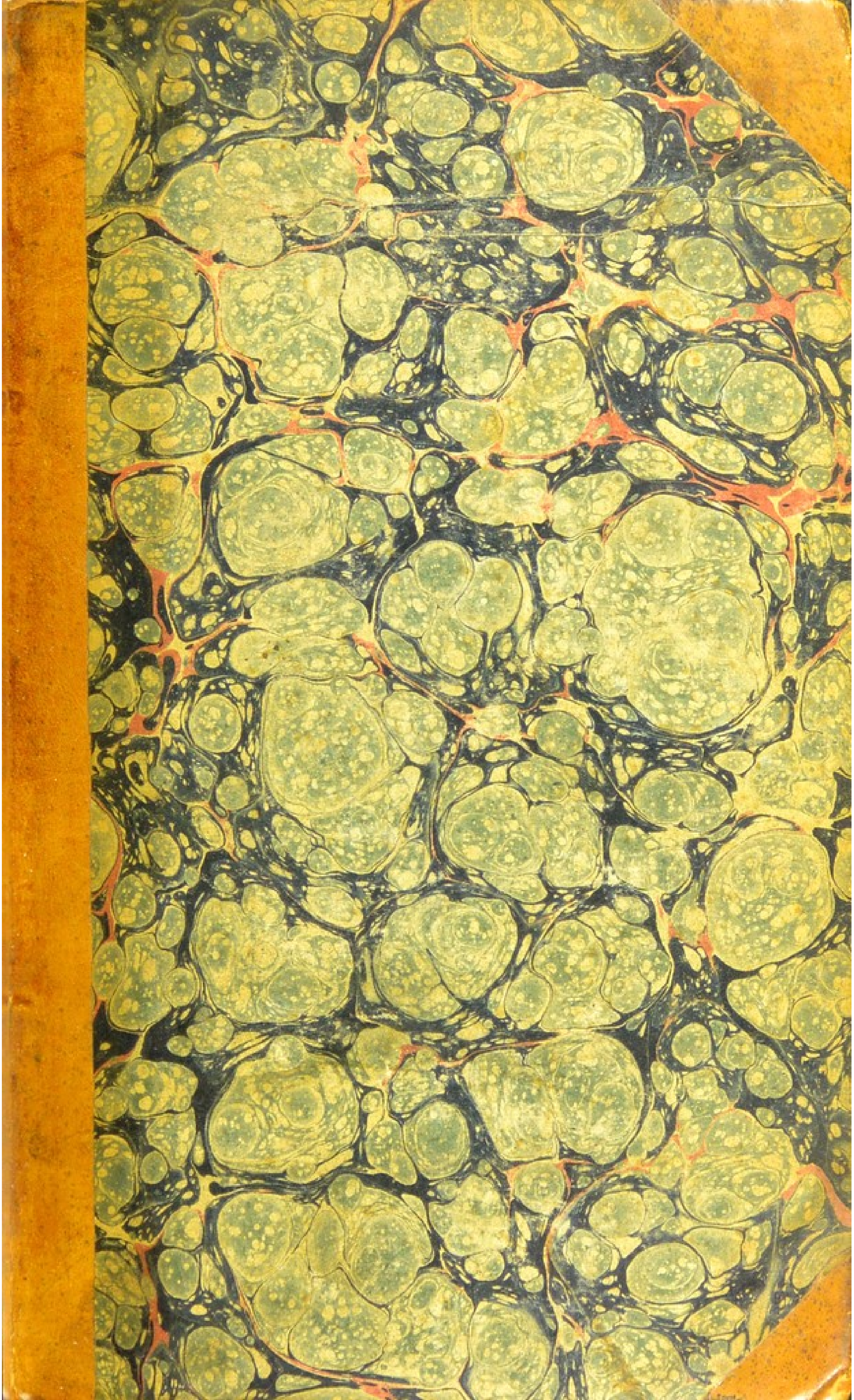
The physical principles of chemistry / by M.J. Brisson ; to which is added, a short appendix by the translator.

Brisson, Mathurin-Jacques, 1723-1806.
Physical Society (Guy's Hospital)
King's College London

London : J. Cuthell, 1801.



THE

PHYSICAL PRINCIPLES
OF
CHEMISTRY.

BY

M. J. BRISSON,

Member of the French National Institute,
And Professor of Chemistry in the Central Schools of Paris.

TO WHICH IS ADDED,

A SHORT APPENDIX,

By the Translator.

ILLUSTRATED WITH SEVEN ENGRAVINGS.

TRANSLATED FROM THE FRENCH.

London:
Printed by G. Auld, Greville-Street,
FOR J. CUTHELL, MIDDLE ROW, HOLBORN;
AND VERNOR AND HOOD, POULTRY.

1801.

AUTHOR'S

PREFACE.

In conſequence of the place which I hold, I have ſeveral duties to diſcharge: I muſt not only teach that ſcience which I profeſs, but, as far as in my power, in ſuch a manner as may be moſt profitable to my pupils: I muſt ſupply them with the means of facilitating their ſtudies: I muſt avoid all reſearches that require too much time; and muſt communicate to them, as briefly as poſſible, that knowledge which forms the object of my leſſons. This taſk, as far as natural philoſophy is concerned, I have already diſcharged, by publiſhing my *Principles of Phyſics*. The ſame taſk remained for me in regard to Chemiſtry; and I now perform it, by publiſhing the preſent Work.

The end of all my labours during life, has been to render myſelf uſeful: if I have ſometimes ſucceeded, I ſhall conſider myſelf fully rewarded for all the pains I have taken.

My firſt ſteps in ſcience were directed towards Natural Hiſtory; to which I was conducted by favourable circumſtances. I lived with *Reaumur* during the laſt eight years of his life. His cabinet of Natural Hiſtory (a collection juſtly celebrated) was well calculated to inſpire me with a taſte for that ſcience. I applied to it; and I may venture to ſay that I made ſome progreſs. My intention was to give a deſcription of the whole animal kingdom; and I indeed publiſhed a plan of the work in one volume, in which I treated of Quadrupeds and Cetaceous Animals. I then publiſhed my *Ornithology*, in ſix volumes quarto. On the death of *Reaumur*, his collection was united to that in the *Jardin des Plantes*, which deprived me of the materials abſolutely neceſſary for continuing my labour. Being unable to proceed in that line of ſtudy, I applied to Chemiſtry: but I did not meet with the ſatisfaction I expected, as I found no baſis capable of fixing my ideas. The ableſt chemiſts entertained opinions very different from each other, and often even diametrically oppoſite; but this was not aſtoniſhing, as they had no fixed point to ſet out from. Some conſidered as compounds what others believed to be ſimple ſubſtances (ſuch as ſulphur); and ſome conſidered

ſidered as ſimple ſubſtances what others maintained to be compounds (ſuch as air). Being, therefore, uncertain to which ſide I ought to turn, or whom to follow, I abandoned that ſcience, and applied to Experimental Philoſophy, where I found that preciſion which I wiſhed.

A great number of facts, already demonſtrated, ſerved me as a guide in the courſe of my labours; and I afterwards endeavoured to inſtruct others. I taught Experimental Philoſophy; and have continued to do ſo publicly ſince 1762.

About the year 1772, the moſt eminent chemiſts found that the experiments they had hitherto made were not capable of giving certain reſults, becauſe they ſuffered to eſcape a part of the products which could have furniſhed them with an analyſis of the bodies ſubjected to examination. On this account they made their experiments in ſuch a manner, as to retain the whole of the products; and they were thus able to acquire a knowledge of all the ſubſtances which enter into the compoſition of a body not only as to quality, but even in regard to the quantity of each ſubſtance. By theſe means they

they obtained ſatisfactory reſults; ſo that Chemiſtry became a new ſcience On this renovation of the ſcience, my former taſte for it was revived; I applied to it with ardour, and beſtowed on it ſuch time as I could ſpare from my other purſuits, which turned out to my advantage; for, being appointed Profeſſor of Natural Philoſophy in the Central School *des Quatre-Nations*, as the law enjoined me in that quality to teach at the ſame time the Elements of Chemiſtry, I found myſelf qualified to diſcharge the functions of my office; which would not have been the caſe had I been unacquainted with the latter ſcience.

In diſcharging my functions, I have had occaſion to obſerve, that when giving leſſons of pure phyſics, my auditors, by means of my treatiſe of *Natural Philoſophy*, which ſerves them as a text-book, are enabled to follow me. If they forget any thing, they find it in that work; and next day they can go over the leſſon they received the preceding evening; by which means they are better able to retain it in their memory. But when I give a leſſon of Chemiſtry, thoſe who poſſeſs no knowledge of that ſcience, have nothing to ſerve them as a guide: if if they forget any part of what they have heard, they muſt recur to a number of different works; and in doing ſo, are for the moſt part incapable of making a proper choice. In a word, they have hitherto had no chemical text-book.

To ſupply this deficiency, I compoſed the preſent work. If any able chemiſt had undertaken a ſimilar treatiſe, it might have been better than mine; but to render it as complete as poſſible, I have made uſe of the beſt ſources: I have laid under contribution the works of *Lavoiſier*, *Guyton*, *Chaptal*, *Berthollet*, *Fourcroy*, *Vauquelin*, &c.; and I have arranged the matter, furniſhed by theſe able chemiſts, according to that method which ſeemed moſt likely to anſwer the intended purpoſe. I have endeavoured alſo to give it as much perſpicuity as poſſible. I flatter myſelf that I have omitted nothing neceſſary in an elementary treatiſe, and that I have introduced into it no ſuperfluous articles, nor any thing capable of diſtracting the attention. I ſubmit my Work, therefore, with confidence to the public, and ſolicit its indulgence.

ADVERTISEMENT.

The Reader is requeſted to obſerve, that the Weights and Meaſures which occur in this Work, are given according to the *Old French Standard*: and that, in many caſes, the correſponding *New French Denominations* are added at the bottom of the page, in notes. Tables, to facilitate the converſion of either into the *Engliſh correſponding Denominations*, will be found in the *Appendix*.

TABLE
OF
CONTENTS.

The Figures refer to the Articles, and not to the Pages.

Pure

De-

Sulphur

Nickel

Table

Specific

PHYSICAL PRINCIPLES

OF

CHEMISTRY.

---

1. ALL natural bodies exiſt in one of the three following ſtates: *Aggregation*, *Accumulation*, or *Mixture*.

2. *Aggregation* is an union of parts all ſimilar, which have a certain adheſion to each other; weak in ſome, and in others ſtrong: ſuch is the caſe with a maſs of water, a maſs of oil, a maſs of metal; as gold, ſilver, iron, antimony, biſmuth, &c.

3. *Accumulation* is a collection of ſimilar parts, which have no adheſion to each other; as is the caſe with a heap of wheat, a heap of ſand.

4. *Mixture* is when parts of a different nature are united; as is the caſe with a great number of bodies.

5. The moleculæ of bodies have a certain tendency towards each other, with the cauſe of which we are unacquainted: this tendency, therefore, has been called *Affinity*; it is called alſo *Attraction*.

6. There are two kinds of affinity: the *Affinity of Aggregation*, and the *Affinity of Compoſition*.

7. As the *Affinity of Aggregation* is ſtronger the nearer the conſtituent parts approach to each other, every thing that tends to diſunite them is capable of diminiſhing the force of that affinity: the matter of heat, which has been called *Caloric*, is proper for producing this effect. The effect of caloric is contrary, therefore, to the force of affinity.

8. The *Affinity of Compoſition* conſiſts in a certain kind of attraction exerciſed on each other, by the different bodies in nature. It is by this affinity that compoſitions and decompoſitions are effected. The affinity of compoſition exerciſes its action only between the conſtituent parts of bodies. Two bodies placed cloſe to each other can never blend themſelves into one; but if they be divided and mixed, a combination may take place.

9. The affinity of compoſition is in the inverſe ratio of the affinity of aggregation. The greater

the force, or the ſtronger the affinity by which the conſtituent parts of a body are united, the more difficult it is to decompoſe that body. It is exceedingly difficult to decompoſe metals, becauſe their conſtituent parts are united by a very ſtrong affinity of aggregation. On the other hand, gaſes are eaſily decompoſed, becauſe their aggregation is weak. Nature, therefore, never combines one ſolid with another; but, in order to produce that effect, firſt reduces them to a ſtate of fluidity. Before the compoſition of affinity can take place between two bodies, one of them at leaſt muſt be fluid.

10. When two or more bodies unite by the affinity of compoſition, their temperature changes. The reaſon of this is, that there is either a combination of caloric, which produces cold; or caloric becomes free, which produces heat.

11. The compound which reſults from the combination of two bodies has properties altogether different from thoſe of the conſtituent principles of that compound: the reſult is different in its nature from either of the compounding bodies; it is a new compound, and has new properties.

12. Every body has certain peculiar degrees of affinity for the different ſubſtances preſented to it: if all bodies had the ſame degree of affinity for each other, there would be neither decompoſitions nor new compoſitions: it is on this difference of affini-

ties that all the operations of nature and of the arts are founded.

13. Caloric, or the principle of fire, is the agent employed by nature for balancing the effect of affinity or attraction (7 and 8). If affinity only exiſted, and no caloric, all bodies would be ſolid. By means of the efforts of caloric we have bodies of different degrees of conſiſtence, which depend on the reſpective energy of theſe two forces (7). When affinity prevails, the bodies are in a ſolid ſtate; but when caloric acquires an aſcendency, they are in the gaſeous ſtate; and the liquid ſtate ſeems to be the point of equilibrium between theſe two powers.

14. When a body is heated, it dilates in every direction: if the heat be continued, its moleculæ loſe almoſt entirely their adheſion, and it becomes fluid or even liquid; if the heat be increaſed ſtill more, it aſſumes the gaſeous ſtate, by combining with caloric. This body may afterwards get rid of its caloric with more or leſs eaſe, according to its affinity for it, or according to the affinity of the caloric for the neighbouring bodies.

15. Caloric is contained in bodies in greater or leſs quantity, according to the degree of affinity which it has for them: means have been found to meaſure this quantity (42); and it is this quantity which is called the *Specific Caloric of Bodies.*

16. Caloric exiſts in bodies in two different ſtates, viz. in a free ſtate, and a ſtate of combination. In a free ſtate, it is that which penetrates bodies in every part; which paſſes freely through their pores from one ſurface to another; which cannot be retained in them at pleaſure, and which renders them hotter in proportion as it is preſent in greater quantity. In a ſtate of combination, it is really combined with the moleculæ of theſe bodies, forms a conſtituent part of them, and, in whatever quantity it may be combined, never raiſes their temperature.

17. It is not improbable that light is the ſame ſubſtance as caloric, but differently modified. We are very little acquainted with the nature of this modification; but as the light which illuminates the earth is capable of ſetting bodies on fire, and as the caloric which burns bodies is capable of affording us light, we have ſome reaſon for conſidering theſe two ſubſtances as the ſame. Light produces alſo ſome effects which are peculiar to itſelf: it is the cauſe of the green colour of plants: without light, plants become blanched; and therefore they naturally turn of themſelves, as much as they can, towards that ſide from which the light proceeds; their taſte and ſmell likewiſe depend n it; and hence it happens that the aromatic productions of the ſouthern countries are the ſtrongeſt and beſt.

18. We are acquainted with three ſubſtances, viz. *ſulphur*, *carbon*, and *phoſphorus*, which en-

ter into the compoſition of a great number of bodies.

19. Sulphur appears to be a ſimple ſubſtance, and not a compound of phlogiſton and ſulphuric acid, as aſſerted by Stahl. Sulphur enters into the compoſition of vegetables and animals; for it is produced by their decompoſition; it is found on the walls of privies; it exiſts naturally in ſome plants, ſuch as *the patience-dock*, *ſcurvy-graſs*, &c.; it abounds in coal-mines; it is combined in ore with ſeveral kinds of metal; it is ſublimated in every place where pyrites is decompoſed; and it is found in large quantities in the neighbourhood of volcanoes: in extenſive manufactories it is extracted from pyrites (ſulphuret of copper, or of iron).

20. *Carbon*, or the carbonaceous principle, is pure charcoal diſengaged from every foreign body: it is a ſimple ſubſtance, for hitherto it has not been poſſible to decompoſe it. Carbon exiſts completely formed in vegetables; it may be freed from the oily and volatile principles by diſtillation, and from ſalts, by waſhing it in pure water. To obtain carbon exceedingly pure, it muſt be dried at a ſtrong heat in cloſe veſſels, otherwiſe the laſt portions of water adhere to it in ſuch a manner, that before they are ſeparated they become decompoſed, and form carbonic acid gas and hydrogen gas: carbon exiſts alſo in the animal kingdom, but not in great abundance.

21. *Phoſphorus* ſeems alſo to be a ſimple ſubſtance; for it cannot be decompoſed. It is the radical of that acid which, combined with lime, forms the bones of animals. As theſe bones therefore are real phoſphate of lime, it is from them that phoſphorus can be extracted with moſt advantage.

Formation of the Aeriform Elaſtic Fluids.

22. It is a general and invariable law of nature, that when a body, either ſolid or fluid, is expoſed to heat, its dimenſions are increaſed in every direction (14). To this law there is no exception.

23. When the moleculæ of a ſolid body have been thus ſeparated, if the body be ſuffered to cool, theſe moleculæ again approach each other in the ſame proportion; the body returns, but in an inverſe direction, through the ſame degrees of extenſion; and being reſtored to its former temperature, gradually reſumes its former dimenſions. If it be expoſed to ſtill greater cold, it becomes ſmaller.

24. But as we are not acquainted with any degree of cold which is not ſuſceptible of being increaſed, becauſe we do not know the zero of heat, it thence happens that we have never yet been able to compreſs as much as poſſible the moleculæ of any body, and conſequently the moleculæ of no body touch each other, or at leaſt touch each other only in a very few points:

points: a ſingular concluſion, to which however it is impoſſible to refuſe aſſent.

25. It may be eaſily conceived, that the moleculæ of bodies being thus urged by heat to recede from each other, would have no connection, and that there would be no ſolid bodies were they not retained by a force tending to unite them. This force, by whatever cauſe produced, has been called *Affinity*, or *Attraction*.

26. The moleculæ of bodies are, therefore, ſubject to two contending forces, the one repulſive, the other attractive, between which they are kept in equilibrium. As long as affinity or attraction is the ſtronger, the body remains ſolid: if the attraction becomes weaker, the moleculæ loſe their adheſion, and the body ceaſes to be ſolid (13). Water affords an inſtance of theſe phenomena: below 32° of Fahrenheit's thermometer, it is ſolid, and is called *Ice*; above 32° it becomes liquid; above 212° it aſſumes the vaporific or gaſeous ſtate, and is converted into an aeriform fluid.

27. The ſame thing may be ſaid of almoſt all the bodies in nature: they are ſolid, liquid, or aeriform, according to the relation which exiſts between the attractive force of their moleculæ and the repulſive force of heat; that is, according to the degree of heat to which they are expoſed.

28. Theſe phenomena are the effect of a very ſubtle fluid which inſinuates itſelf between the moleculæ of all bodies; which is the cauſe of heat, and which is called *Caloric* (7).

29. Is light a modification of caloric? or, Is caloric a modification of light? The latter is not improbable (17). But it is certain that things which produce different effects, ought to be diſtinguiſhed by different names. We ſhall therefore diſtinguiſh light from caloric, acknowledging however that they poſſeſs ſome qualities in common (17), and that, under certain circumſtances, they combine nearly in the ſame manner, and produce in part the ſame effects.

30. But in what manner does caloric act on bodies? As it penetrates through all their pores, and ſince no veſſel can confine it (16), it is impoſſible to become acquainted with its properties, except by effects which, for the moſt part, are fugitive and difficult to be examined. When we can neither ſee nor handle a body, we muſt be on our guard againſt flights of the imagination, which tend always to lead us beyond the boundaries of truth.

31. We have already ſaid, that the ſame bodies become ſolid, liquid, or aeriform, according to the quantity of caloric by which they are penetrated; according as the repulſive force of the caloric is inferior,

rior, equal, or ſuperior, to the attraction of the moleculæ. If there exiſted only theſe two forces, bodies would not remain liquid, but at one certain degree of temperature; they would paſs with rapidity from the ſolid to the aeriform ſtate: water, for example, in ceaſing to be ice, would begin to boil, and by combining itſelf with caloric (14) would be tranſformed into vapour, into gas: in a word, into an aeriform fluid. What prevents this effect, is a third force, ariſing from the preſſure of the atmoſphere. For this reaſon, water remains liquid from 32 to 212 degrees (26). If this preſſure be diminiſhed it boils, and is ſooner converted into vapour, and at an inferior degree of temperature.

32. It may therefore be ſeen, that without the preſſure of the atmoſphere we ſhould have no conſtant liquids: no body would be in that ſtate but at the exact moment of its melting; the next ſucceſſive degree of heat would render it aeriform: we even ſhould have no aeriform fluids; for at the moment when the attractive force of the moleculæ was overcome by the repulſive force of the caloric, theſe moleculæ would recede from each other indefinitively, unleſs collected by their gravity to form an atmoſphere.

33. This may be proved by the following experiment:—Place a ſmall veſſel, A, (fig. 1.) two inches and one fourth in height, and thirteen and one fourth lines in diameter, completely filled with

ether,

ether, and well cloſed by a piece of bladder, under a receiver having adapted to it a barometer and thermometer, and furniſhed with a ſharp pointed rod of iron, paſſing through a leather collar: exhauſt the receiver, and pierce the bladder by means of the rod F; the ether will immediately boil up with great rapidity, and fill the receiver B C D, with its vapour. If the ether be in ſufficient quantity for a few drops of it to remain liquid, the elaſtic fluid which has been produced will be capable of ſupporting the mercury in the barometer G H, at the height of eight or ten inches in winter, and of twenty or twenty-five in ſummer. During the vaporization there is produced a conſiderable degree of cold, indicated by the falling of the liquor in the thermometer: the cauſe of this is, that the ether does not aſſume the aeriform ſtate but by combining with a large quantity of caloric, which, becauſe it is combined, no longer excites any degree of heat. If the apparatus be ſuffered to reſume the temperature of the place, and if the air be again admitted below the receiver, there will be produced a degree of heat, which will be indicated by the thermometer riſing: the reaſon of this is, that the vapour, in conſequence of the new preſſure it experiences from the air, returns to the liquid ſtate by abandoning its caloric, which, becoming free, excites heat.

In this experiment you only intercept the preſſure of the atmoſphere; and the effects which then reſult prove two things: 1ſt, That in our temperature, ether would be always an aeriform fluid, were it not for the preſſure of the atmoſphere; 2d, That, in the paſſage from the liquid to the aeriform ſtate, a conſiderable degree of cooling takes place; and that, in the paſſage from the ſtate of aeriform fluid to that of liquid, a great deal of heat is produced, which happens in all ſimilar caſes.

34. The above experiment (33) will ſucceed with all fluids ſuſceptible of evaporation; ſuch as alcohol, water, and even mercury. But the vapour of alcohol ſupports the mercury of the barometer only at the height of one inch in winter, and of four or five inches in ſummer: the vapour of water ſupports it at the height of a few lines, and that of mercury at the height of no more than ſome fractions of a line. In theſe caſes, therefore, a leſs quantity of fluid is vaporized, conſequently there is leſs caloric combined, and leſs cooling, which agrees very well with the reſult of experiment.

35. We may ſtill obtain other proofs that the aeriform ſtate is a modification of bodies, and that it depends on the temperature and the preſſure which they experience. Under the preſſure of our atmoſphere, which I ſuppoſe capable of ſupporting the mercury of the barometer at the height of twenty-eight inches, ether enters into ebullition at 106·25 degrees of heat, ſpirit of wine, or alcohol, at 183 degrees; and water at 212 degrees. But ebullition is the moment of paſſage from the liquid to the aeriform

form ſtate; and therefore if theſe liquors be kept at a temperature a little higher than the above-mentioned degrees, you will obtain them in the ſtate of aeriform fluids. To prove this, you may make the following experiment:—

Immerſe into a veſſel, A B C D, (fig. 2.) filled with water, heated to 110 or 114 degrees, a bottle F, filled with the ſame water, and having its mouth inverted: introduce under the water into the mouth of the bottle the bent neck of a ſmall matraſs, *b a*, containing ſulphuric ether: the ether will almoſt immediately begin to boil, and the caloric combining itſelf with it, will convert it into an aeriform fluid, capable of filling ſeveral bottles.

By this experiment it may be ſeen that ether is nearly ſo volatile, that it cannot exiſt in our temperature but in the aeriform ſtate, and that if the preſſure of the atmoſphere were equal only to that of a column of mercury twenty or twenty-four inches in height, we could never obtain it in the liquid ſtate, at leaſt in ſummer. The caſe would be the ſame on high mountains, on account of the diminution of the preſſure of the atmoſphere. This experiment will ſucceed beſt with nitrous ether, becauſe it is vaporized at a ſtill lower degree of temperature.

36. Water and alcohol will exhibit the ſame phenomena, if they be expoſed to a degree of heat ſuperior

perior to that which brings them to the point of ebullition.

Exp. Fill with mercury a glaſs jar, A (fig. 3) and having turned its mouth downwards, and immerſed it in a diſh B, filled alſo with mercury, introduce into it about two drams of water, which will riſe to the top of the jar C D; then immerſe the whole into an iron boiler E F H G, placed on a furnace I K, and filled with ſalt water in a ſtate of ebullition, the temperature of which may be raiſed to 223 degrees. As ſoon as the water in the upper part of the jar C D, has attained to the temperature of about 212 degrees it begins to boil, and is converted into an aeriform fluid, which fills the whole jar A.

37. Here then we have ſeveral ſubſtances which become aeriform fluids at degrees of temperature not very remote from thoſe in which we live. We ſhall find hereafter that there are ſeveral others, ſuch as the muriatic acid, the carbonic acid, the ſulphurous acid, ammonia, &c. which conſtantly remain in the aeriform ſtate at the uſual degree of heat and preſſure which we experience; and thence we may eſtabliſh the general principle, already announced (27), that almoſt all the bodies in nature are ſuſceptible of exiſting in three different ſtates, the ſolid, liquid, and aeriform; and that theſe three ſtates of the ſame body depend on the quantity of caloric which penetrates it, or is combined with it.

38. To

38. To theſe aeriform fluids we give the name of *Gas*, and in each of them we diſtinguiſh two things: the caloric, which in ſome manner is the ſolvent; and the ſubſtance combined with it, which forms its baſe.

39. We have already ſaid (26) that the moleculæ of bodies are in a ſtate of equilibrium between their attractive force, which tends to make them approach each other, and the efforts of caloric, which tend to ſeparate them. Thus, caloric not only ſurrounds bodies on every ſide, but it fills the interſtices left between their moleculæ, in the ſame manner as fine ſand would fill the intervals contained between ſmall balls of lead put into a veſſel. Theſe interſtices are not of the ſame capacity in all bodies; this capacity depends on the ſize of the moleculæ, their figure, and the diſtance left between them, according to the relation which exiſts between the force of their attraction and the repulſive force exerciſed by caloric.

It is in this ſenſe that we muſt underſtand the expreſſion, *Capacity of bodies for admitting caloric between their moleculæ*. Let us illuſtrate this expreſſion by an example:—If you immerſe into water different bits of wood, equal in volume, and each of a known weight, the water will introduce itſelf into their pores, by which means they ſwell up, and their weight is increaſed; but each kind of wood admits a different quantity of water: thoſe moſt porous admit the greateſt quantity, and thoſe moſt compact the leaſt. The quantity they admit depends alſo on the nature of the moleculæ of each kind of wood, and on the greater or leſs affinity which it has for water: reſinous woods, for example, admit very little, though they are exceedingly porous. Different kinds of wood, therefore, have a different capacity for receiving water. The caſe is the ſame in regard to bodies immerſed in caloric: different bodies have a different capacity for admitting it; ſome admit more, and ſome leſs.

41. After this illuſtration, it will be eaſy to conceive an idea of what is meant by the following expreſſions:—*Specific Caloric of Bodies*, *Capacity for admitting Caloric*, *Free Caloric*, *Combined Caloric*, *Senſible Heat*, *Latent Heat*; expreſſions which are not ſynonymous, but which have each a fixed and determined meaning. Let us eſtabliſh theſe meanings by definitions.

42. By the *ſpecific caloric of bodies*, is underſtood that quantity of caloric, whether free or combined, which is contained in theſe bodies, and which, by becoming perfectly free, is reſpectively neceſſary to elevate the ſame number of degrees, the temperature of ſeveral bodies equal in weight. This quantity is not the ſame in all bodies: it depends on the greater or leſs adheſion of their moleculæ, and the diſtance between theſe moleculæ. It is this diſtance

tance, or rather the ſpace reſulting from it, that has been called *Capacity for admitting Caloric.*

43. *Free Caloric* is that which is not engaged in any combination. We live amidſt a ſyſtem of bodies with which caloric has adheſion ; and it thence reſults that we never obtain this principle in a ſtate of abſolute freedom : there is always a portion of it in combination.

44. *Combined Caloric* is that which is confined in bodies by the force of affinity or attraction, and which conſtitutes a part of their ſubſtance, and even of their ſolidity.

45. *Heat* is occaſioned by free caloric (43) or caloric becoming free : it is the effect produced on our organs by the introduction of caloric diſengaged from ſurrounding bodies. In general, we experience no ſenſation, but in conſequence of ſome movement ; and it may be eſtabliſhed as an axiom, that *Where there is no movement, there is no ſenſation.* When we touch a cold body, the caloric paſſes from our hand into that body, and we experience a ſenſation of cold ; in the contrary caſe, when we touch a warm body, the caloric paſſes from that body into our hand, and we experience a ſenſation of heat. But, if the body and the hand have the ſame degree of temperature, we experience no ſenſation either of cold or heat, becauſe there is no tranſmiſſion of caloric. In a word, becauſe there is no movement.

46. By *latent heat* (an expreſſion certainly improper) is underſtood heat not ſenſible to our organs; that which, ſtrictly ſpeaking, is not *heat:* it is combined caloric (44) which occaſions no heat. This combined fluid is ready to make us feel heat; but for that purpoſe, it muſt firſt become free (43).

47. It is not improbable that the great elaſticity of aeriform fluids ariſes from that of the caloric united to them, and which appears to be a body highly elaſtic by its nature. This, indeed, is explaining elaſticity by elaſticity, and removing a difficulty without reſolving it; but ſince our knowledge extends no farther, we muſt admit this conjecture till ſomething more ſatisfactory can be obtained.

Formation and Conſtitution of the Atmoſphere of the Earth.

48. What has been here ſaid, will ſerve to give ſome idea of the manner in which our atmoſphere has been formed. It may readily be conceived, that it muſt be the reſult and mixture, 1ſt, Of all thoſe ſubſtances ſuſceptible of remaining in an aeriform ſtate at the uſual degree of heat and preſſure which we experience; 2d, Of all thoſe fluid or concrete ſubſtances ſuſceptible of being diſſolved in that aſſemblage of different gaſes.

49. Should our earth be ſuddenly tranſported to a region much hotter (to that of Mercury, for example) many of our liquids would become elaſtic fluids, and the reſult would be new decompoſitions and combinations, unleſs theſe ſubſtances ſhould experience a very ſtrong degree of preſſure, as the water does in Papin's digeſter.

50. On the other hand, if our earth ſhould be tranſported to a very cold region, moſt of our fluids would be transformed into ſolid bodies: a part of our aeriform ſubſtances would become liquid, or even ſolid, &c.

51. This ſuppoſition of two extremes ſhews, 1ſt, That *ſolidity*, *liquidity*, and *elaſticity*, are three different ſtates of the ſame ſubſtance; three modifications through which almoſt all theſe ſubſtances may paſs, and which depend only on the quantity of caloric that penetrates them; 2d, That our atmoſphere is a compound of every fluid capable of exiſting in a conſtant ſtate of elaſticity, at the degree of heat and preſſure which we experience, and which are not ſoluble in water, or, at leaſt, very little ſo.

52. It is well known that among our fluids there are ſome, ſuch as water and alcohol, or ſpirit of wine, that may be mixed with each other in all proportions, and which never afterwards ſeparate; others, as mercury, water, and oil, after they have

been mixed, ſpeedily ſeparate again as ſoon as they are left at reſt, and they then arrange themſelves according to the ratio of their ſpecific gravities. The caſe muſt be the ſame in the atmoſphere: the lighteſt fluids, ſuch as the inflammable ones, muſt form ſtrata that float on the air; and it is not improbable that it is at the place where theſe ſtrata come into contact with the air that certain igneous phenomena are produced.

Of the Elaſtic Aeriform Fluids.

53. The elaſtic aeriform fluids are thoſe which have aſſumed the form of the atmoſpheric air, and which exhibit the ſame appearances (26 *et ſeq.*) There are two kinds of theſe fluids; one of which comprehends thoſe called *Permanent*; and the other, thoſe known under the name of *Non-Permanent* (37). To have a proper idea of this diſtinction, the reader muſt recollect what has been before ſaid (26 and 31): 1ſt, That the moleculæ of bodies are ſubject to two contending forces, the one repulſive, the other attractive, between which they are kept in a ſtate of equilibrium; 2d, That the ſame bodies become ſolid, liquid, or aeriform, according to the quantity of caloric that pervades them; 3d, That caloric exiſts in bodies in two different ſtates, *viz.* in a ſtate of freedom (43) and a ſtate of combination (44).

This combined caloric is often diſengaged during the decompoſition of bodies: heat, therefore, is in that caſe produced, as in putrefaction. In certain combinations caloric is abſorbed alſo; and on ſuch occaſions there is a production of cold, as in evaporation.

54. The *permanent* elaſtic fluids are thoſe which contain caloric in a ſtate of combination (44); and theſe fluids retain their aeriform ſtate at every degree of temperature; for this reaſon they have been called *Permanent*. Of this kind are the air and the different gaſes.

55. The *non-permanent* elaſtic fluids are thoſe which contain a certain quantity of caloric in a ſtate of freedom (43); and theſe fluids cannot retain their aeriform ſtate but while expoſed to little compreſſion, or at a high temperature, and more or leſs according to their different denſities. On this account they have acquired the name of *Non-Permanent*.

At preſent, we ſhall treat only of the permanent elaſtic fluids, and defer ſaying any thing farther of the reſt till we come to examine the nature of water and its effects.

56. The permanent aeriform elaſtic fluids are all compreſſible, elaſtic, tranſparent, colourleſs*, in-

---

* We muſt except oxygenated muriatic gas, which is of a greeniſh-yellow colour.

viſible, and incapable of being condenſed into liquor by cold. Some of them exiſt naturally without the aſſiſtance of art, though they may be obtained in that manner; others are merely the production of artificial means. Some of them are completely ſoluble in water; others are inſoluble, or, at leaſt, are ſoluble in a very ſmall degree. Different means, therefore, muſt be employed to procure them, as will be mentioned hereafter (65).

57. Theſe fluids are divided into two claſſes. The firſt comprehends thoſe which are *vivifying*; that is to ſay, which ſerve for and are eſſential to the purpoſes of reſpiration in men and animals, and to the combuſtion of bodies. Of this kind are *atmoſpheric air*, and *pure* or *vital air*, called *Oxygen Gas*.

58. The ſecond claſs comprehends thoſe which are of a *ſuffocating* nature; that is to ſay, which can ſerve neither for reſpiration nor for the combuſtion of bodies. Of this kind are all the other *gaſes*.

59. Theſe ſuffocating fluids are divided into three orders. The firſt comprehends thoſe which are not ſaline; that is to ſay, which are neither acid nor alkaline; the ſecond, thoſe which are ſaline; that is to ſay, either acid or alkaline; the third comprehends thoſe which are inflammable, and which are called *Hydrogen Gaſes*.

60. *Firſt Order.*—The non-ſaline gaſes are in number three, *viz. Atmoſpheric* or *Azotic Gas,* called alſo *Mephitic Gas, Nitrous Gas,* and *Oxygenated Muriatic Gas.*

61. *Second Order,*—The ſaline gaſes are five in number, *viz. Carbonic Acid Gas, Muriatic Acid Gas, Sulphurous Acid Gas, Fluoric Acid Gas,* and *Ammoniacal* or *Alkaline Gas.*

62. *Third Order.*—The inflammable or hydrogen gaſes are all of the ſame ſpecies; but there are ſeveral varieties. We have, therefore, *Pure Hydrogen Gas,* the varieties of which are *Sulphurated Hydrogen gas, Phoſphorized Hydrogen Gas, Carbonated Hydrogen Gas, Carbonic Hydrogen Gas,* and the *Hydrogen Gas of Marſhes.*

To exhibit all theſe gaſes at one view, I have ſubjoined the following methodical table :—

63. *Methodical Table of the Aeriform Elaſtic Fluids.*

ELASTIC FLUIDS.

Vivifying, - CLASS I.		
	Atmoſpheric air,	1
	Pure vital air, or oxygen gas,	2
Suffocating, CLASS II.		
Non-ſaline, - *Order* 1.		
	Azotic gas,	3
	Nitrous gas,	4
	Oxygenated muriatic gas,	5
Saline, - - *Order* 2.		
	Carbonic acid gas,	6
	Muriatic acid gas,	7
	Sulphurous acid gas,	8
	Fluoric acid gas,	9
	Ammoniacal gas,	10
Inflammable, - *Order* 3.		
	Pure hydrogen gas,	11
	Sulphurated hydrogen gas,	12
	Phoſphoriſed hydrogen gas,	13
	Carbonated hydrogen gas,	14
	Carbonic hydrogen gas,	15
	Hydrogen gas of the marſhes,	16

64. All theſe gaſes exhibit the appearances of air; and they even poſſeſs ſome of its properties, as tranſparency, ſuſceptibility of compreſſion, expanſibility, and elaſticity. It was for this reaſon, no doubt, that Hales, Boyle, Prieſtley, and ſeveral other philoſophers and chemiſts, gave to all theſe fluids the name of *Air*. But, as they differ very much from air in a great number of other properties,

ties, and particularly in being abſolutely incapable to maintain animal life and the combuſtion of bodies, it has been concluded, and not without reaſon, that they ought not to be confounded with air. To diſtinguiſh them, therefore, it has been thought proper to adopt the name of *Gas*, which Vanhelmont, and other chemiſts, anterior to Hales, had given to thoſe fluids known in their time; for the general knowledge of *gaſes* is older than the period of Paracelſus.

65. We have already ſaid (56) that of theſe fluids ſome are inſoluble in water, and others completely ſoluble. To extract and obtain them, two kinds of apparatus, therefore, are neceſſary: one in which water is uſed for thoſe that are inſoluble; and the other conſtructed with mercury for thoſe which are ſoluble in water, and which could not be received in that liquid without being immediately diſſolved in it. Theſe kinds of apparatus were invented by Prieſtley, who made a ſeries of ingenious experiments on the above fluids.

66. Every aeriform fluid is compoſed of a baſe, either ſimple or compound, and combined with caloric. Theſe fluids are not entirely contained in the ſubſtances uſed for extracting them: theſe ſubſtances contain only their baſes which at the time of extraction combine with caloric, and by theſe means aſſume the ſtate of aeriform elaſtic fluids. That the reader may have a better idea of the nature

ture of theſe fluids, I ſhall here point out the baſes of each of them.

Baſes of the Aeriform Elaſtic Fluids.

67. I. Atmoſpheric air is compoſed of two elaſtic fluids, merely mixed together, one of which is pure vital air, called *Oxygen Gas:* the other is a mephitic ſubſtance, called *Azotic Gas*: the air of our atmoſphere contains 28 parts of the former, and 72 of the latter. Its baſe, therefore, is compoſed of *oxygen* and *azote.*

68. II. The baſe of pure air or oxygen gas, is the acidifying principle, without which there would be no acid, and which, for that reaſon, is called *Oxygen*; that is to ſay, the *generator of acids.*

69. III. The baſe of azotic gas, when that gas is alone, is a ſubſtance incapable of maintaining animal-life, and for this reaſon it has been called *Azote*; that is to ſay, the *depriver of life.* It is indeed true, that this name is applicable to all the ſuffocating fluids; but as this is the one moſt common, and as it continually ſurrounds us *, the above appellation has been given to it in preference.

70. IV. The baſe of nitrous gas is the ſame *azote* combined with a little *oxygen.*

---

* It will be ſeen hereafter (135) that it is of ſome utility to us.

71. V. The baſe of oxygenated muriatic gas is *muriatic acid* ſurcharged with *oxygen* and dephlegmated.

72. VI. The baſe of carbonic acid gas is *oxygen*, holding in ſolution *carbon*, which is charcoal in its ſtate of purity.

73. VII. The baſe of muriatic acid gas is *muriatic acid* deprived of its ſuperabundant water.

74. VIII. The baſe of ſulphurous acid gas is *ſulphuric acid*, which has loſt a part of its *oxygen*, or which is ſurcharged with ſulphur; that is to ſay, which by theſe means has become ſulphurous acid, and which is deprived of its ſuperabundant water.

75. IX. The baſe of the fluoric acid gas is *fluoric acid*, deprived of its ſuperabundant water.

76. X. The baſe of ammoniacal gas is *ammonia*, or cauſtic volatile alkali, deprived of its ſuperabundant water.

77. The four laſt gaſes are acids or alkalies, as highly concentrated as they can be, ſince they are deprived of all their ſuperabundant water.

78. XI. The baſe of pure hydrogen gas is an unknown ſubſtance, to which chemiſts have given the

the name of *Hydrogen*; that is to ſay, the *generator of water*.

79. XII. The baſe of ſulphurated hydrogen gas, called alſo Hepatic Gas, is *hydrogen*, holding *ſulphur* in ſolution.

80. XIII. The baſe of phoſphorized hydrogen gas is *hydrogen*, holding phoſphorus in ſolution.

81. XIV. The baſe of carbonated hydrogen gas is *hydrogen*, which holds carbon in ſolution.

82. XV. The baſe of carbonic hydrogen gas is *hydrogen*, mixed in different proportions with the baſe of carbonic acid gas; that is to ſay, *oxygen* holding *carbon* in ſolution.

83. XVI. The baſe of the hydrogen gas of marſhes is *hydrogen*, mixed in different proportions with the baſe of azotic gas; that is to ſay, *azote*.

CLASS I.

Of the Vivifying Elaſtic Fluids.

84. Theſe fluids are thoſe eſſentially neceſſary for the reſpiration of man and of animals, and for the combuſtion of bodies. Of this kind is atmoſpheric air and pure vital air, called Oxygen Gas (57).

1. *Atmoſpheric Air.*

85. *Atmoſpheric air* was long conſidered to be an element, a ſubſtance, all the parts of which, ſimilar to each other, were ſimple and indecompoſable. It is now known that atmoſpheric air is eſſentially compoſed of two elaſtic fluids, very different from each other (67) *viz. oxygen gas*, a fluid abſolutely neceſſary for the reſpiration of man and animals, as well as for the combuſtion of bodies; and a mephitic fluid called *Azotic Gas*, in which burning bodies are immediately extinguiſhed, and animals ſpeedily ſuffocated.

86. The firſt of theſe fluids, *oxygen gas*, is deſtroyed or abſorbed by the combuſtion of every body whatever: the ſecond, *azotic gas*, is abſolutely incombuſtible. To be convinced of this fact, you may make the following experiment :—

Exp.—On the ſhelf EF (*fig.* 4.) of the pneumatic tub, place a bell glaſs (*fig.* 5.) filled with atmoſpheric air, ſo as to cover a lighted taper floating on a ſmall bit of wood. The activity of the flame will always continue to decreaſe till the taper is at length extinguiſhed ; and, in the mean time, the water of the tub will aſcend into the bell. When the apparatus has cooled and returned to the temperature which exiſted before the experiment, you will

will find about a fourth part of the bell filled with water.

87. This water has aſſumed the place of the fluid abſorbed; what remains is only mephitic gas, capable of ſuffocating animals and extinguiſhing burning bodies. The reſpirable fluid, therefore, has been deſtroyed by the combuſtion. It has been proved by experiments made with great care, that in well conſtituted air, 100 parts in volume contain 28 of oxygen gas and 72 of azotic gas. The azotic gas which remains under the bell is not pure: in this caſe, it is mixed with another elaſtic fluid, carbonic acid gas, which is always produced by all burning bodies. This laſt gas is readily abſorbed by lime-water, with which it combines to form chalk: nothing, therefore, is neceſſary but to agitate this mixture ſtrongly in lime-water: the carbonic acid gas will be abſorbed, and the azotic gas will remain pure.

88. Atmoſpheric air, therefore, is not a ſubſtance all the parts of which are homogenous, ſince ſome of them are deſtroyed by the combuſtion of bodies, and others of them remain unalterable by that proof. In atmoſpheric air, then, there is only about a fourth part fit for reſpiration and combuſtion, while the other three-fourths are not ſo.

Let us now examine ſeparately the two fluids of which atmoſpheric air is compoſed.

2. *Pure, or Vital Air, called Oxygen Gas.*

89. Pure air is compoſed of a baſe called *Oxygen*, combined with a large quantity of caloric (68). This baſe has been diſtinguiſhed by the name of *Oxygen*; that is to ſay, the *generator of acids*, becauſe it is the real *acidifying principle:* the principle without which there would be no acid. To this air Prieſtley gave the name of *Dephlogiſticated Air.*

90. This fluid exiſts naturally in our atmoſphere, and forms about a fourth part of it; but it may be obtained alſo by the aſſiſtance of art. It may be extracted merely by heat from a great number of ſubſtances, but, in particular, from native oxide of manganeſe, and thoſe metallic oxides which can be revived without the addition of inflammable matters, ſuch as the oxides of mercury. Mercury precipitated *per ſe*, and *the red precipitate*, furniſh a large quantity of it. The caſe is the ſame with native oxide of manganeſe.

91. This fluid, however, is not entirely contained in theſe ſubſtances; they contain only the baſe of it which is oxygen; for metals do not calcine or burn but by combining with oxygen, which aſſumes in them the ſolid ſtate, and increaſes their weight. This oxygen may be afterwards expelled by heat; and as it then combines with caloric, it paſſes to the ſtate of elaſtic fluid, and thus we have *pure air*. During

this proceſs the metal, by loſing the oxygen, which had reduced it to the ſtate of oxide, reſumes its metallic ſplendor, and loſes the weight it had acquired by becoming oxidated.

92. Hence it appears that combuſtion is nothing but a combination of oxygen with the combuſtible body: it is not the combuſtible body therefore that is decompoſed; it is the pure air.

93. Pure air emanates alſo from green plants, when expoſed to the ſun with water, but not from flowers and roots, as has been proved by Ingenhouſs. In this operation the leaves of the vegetables decompoſe the water by abſorbing hydrogen, one of its conſtituent parts, and by ſuffering oxygen, the other conſtituent part of that liquid (275), to be diſengaged in the ſtate of pure air. Light, no doubt, contributes to the decompoſition, ſince it does not take place without the contact of that fluid, as has been likewiſe proved by Ingenhouſs.

94. Pure air is a little heavier than atmoſpheric air: its ſpecific gravity is to that of the latter as 108⅘ is to 100; and to that of diſtilled water, as 13·3929 is to 10000; ſo that the cubic inch of this fluid weighs 0·5 of a grain, and the cubic foot one ounce 4 drams[*].

---

[*] According to the new French ſyſtem of weights and meaſures, a cubic inch of this fluid weighs 26·557 milligrammes; and a cubic foot 45 grammes, 891 milligrammes.

95. Pure

95. Pure air exhibits no ſign of acidity, though it is the generator of all the acids, the principle without which there would be no acid; for it does not redden blue vegetable colours, as all the acids do.

96. Pure air is not abſorbed by water; it is not at all ſoluble in that fluid, but it is abſorbed almoſt entirely by nitrous gas, with which its oxygen combines, as we ſhall ſhew hereafter (197); and this combination, which is entirely ſoluble in water, forms nitrous acid.

97. Pure air ſerves, in an eminent degree, for the purpoſes of reſpiration. An animal incloſed in a ſpace filled with pure air, would live in it four times as long as it would do if the ſame ſpace were filled with atmoſpheric air; for, in the firſt caſe, the animal would find four times as much fluid fit for reſpiration as it would in the other, becauſe atmoſpheric air contains only a fourth part of pure air (90).

98. Pure air then is the only fluid proper for maintaining animal life: the reaſon is as follows:— A great deal of caloric is required for the ſupport of life, and pure air is the only one of all the elaſtic fluids which can furniſh it: 1ſt, Becauſe it contains more of it than the reſt; 2d, Becauſe its baſe has a greater affinity for carbon and hydrogen than the baſes of the other gaſes: but a certain quantity of carbonated hydrogen gas is diſengaged from the

blood

blood in the lungs; the pure air inſpired combines then with theſe two ſubſtances, the hydrogen and carbon. A part of this air, combining with the carbon, forms, by parting with a portion of its caloric, carbonic acid gas (215): this may be conſidered as a real combuſtion of carbon. Another part of the pure air combines with the hydrogen, and by giving up all its caloric, forms water: it is theſe two portions of caloric, abandoned by the pure air, that maintain animal heat and life.

99. But ſince in reſpiration there is diſengaged from pure air a very large quantity of caloric, it is probable that this fluid, if reſpired for a certain time, would be prejudicial to animals, by furniſhing them with too large a quantity of caloric, which would rarefy their blood too much, and increaſe the rapidity of its circulation: the reſult therefore would be a a violent fever and inflammation of the lungs, as Lavoiſier proved by an experiment.

100. Pure air is the only elaſtic fluid in which bodies can burn; for in atmoſpheric air, in which they burn alſo, it is only the pure air contained in it that is fit for combuſtion, becauſe combuſtion is merely a combination of oxygen with the combuſtible body (92); but when pure air is freed from every other fluid, combuſtion takes place in it with a great deal of heat and light. This is owing to the rapid ſeparation of caloric, which aſſumes the free

ſtate by quitting the baſe of this air, in proportion as that baſe becomes fixed in the burning body.

101. If a fire be urged by a current of pure air, its activity will be conſiderably increaſed, as has been proved by Prieſtley and Lavoiſier. We are acquainted with no degree of heat ſo ſtrong as that excited in this manner.

102. The baſe of pure air (oxygen) is one of the conſtituent parts of water, as ſhall be proved hereafter (275).

103. Pure air, or oxygen gas, may be eaſily decompoſed by phoſphorus, ſulphur, and charcoal, as has been proved by experiment.

To operate with more accuracy in ſuch experiments, you muſt not employ atmoſpheric air, but, as much as poſſible, pure vital air, or oxygen gas.

104. *Exp.* A receiver capable of containing five or ſix pints*, and placed over a water pneumatic-tub (fig. 4), was filled with oxygen gas, and afterwards removed to a mercurial apparatus (fig. 6), by means of a glaſs-capſule introduced below it; the ſurface of the mercury was well dried with a piece of blotting-paper, and ſixty-one grains and a fourth †

---

* 5 or 5½ litres.

† 3¼ grammes.

of Kunkel's phoſphorus, diſtributed in two porcelain cups ſimilar to that ſeen at D (*fig.* 6) were introduced under the bell A; and that the operator might be able to kindle each of theſe bits of phoſphorus ſeparately, and that the inflammation might not be communicated from the one to the other, one of them was covered with a ſmall ſquare of glaſs. When every thing was thus arranged, the mercury in the bell A was raiſed to the height E F, by ſucking out part of the gas by means of a glaſs ſyphon, G H I, introduced below the bell, and which was prevented from being filled with mercury in paſſing through that fluid by a ſmall bit of paper I twiſted round its upper extremity. The bits of phoſphorus in the two cups were then ſucceſſively kindled by means of a piece of bent wire (*fig.* 7) which had been made red hot, beginning with that portion of the phoſphorus not covered with the glaſs.

The combuſtion took place with great rapidity, producing a brilliant flame and the diſengagement of a conſiderable degree of light and heat. At firſt there was a great rarefaction of the oxygen gas, occaſioned by the heat which cauſed the mercury to deſcend; but it afterwards roſe much higher, for a conſiderable abſorption took place: at the ſame time the inſide of the bell became covered with white light flakes, which were concrete phoſphoric acid.

105. The

105. The quantity of oxygen gas employed was 162 cubic inches[*]: after the abſorption there remained 23¼ cubic inches[†], ſo that the quantity of oxygen gas abſorbed was 138¼ cubic inches[‡], or 69·375 grains[§]. There were only about 45 grains[||] of phoſphorus burnt; for about 16¼ grains[**] were found remaining in the cups.

106. In this experiment 45 grains of phoſphorus, combined with 69·375 grains of oxygen and formed 114·375 grains[††] of white flakes, which were real concrete phoſphoric acid; from which we may conclude, that 154 pounds of oxygen would be required to ſaturate 100 pounds of phoſphorus, from which there would reſult 254 pounds of concrete phoſphoric acid.

107. This experiment proves that, at a certain temperature, oxygen has more affinity for phoſphorus than it has for caloric; conſequently that phoſphorus decompoſes oxygen gas by ſeizing on its baſe, and that the caloric, then aſſuming a ſtate of liberty, paſſes into the ſurrounding bodies, and produces in them heat.

---

[*] About 3213493 cubic millimetres.

[†] 461196 cubic millimetres.

[‡] 2742379 cubic millimetres.

[§] 3 grammes, 685 milligrammes.

[||] 2 grammes, 390 milligrammes.

[**] 863 milligrammes.

[††] 6 grammes, 75 milligrammes.

108. The following experiment, made on a larger ſcale, proves the juſtneſs of the preceding reſults in a manner more rigorous and exact. Take a large glaſs balloon, A, (*fig.* 8.) the aperture of which, E F, is about three inches in diameter, and cover the aperture with a plate of ground glaſs, pierced with two holes to receive the two tubes, *y y y*, *x x x*, furniſhed with cocks. Before you cover it with the plate, introduce into it a ſupporter, C B, with a porcelain cup, D, containing 150⅔ grains[*] of phoſphorus; and after you have cloſely ſhut the balloon, by luting on the glaſs plate, exhauſt the balloon of air by connecting the tube *x x x* with an air-pump. Then weigh the whole apparatus by a nice balance, and fill the balloon with oxygen gas by means of the tube *y y y*, connected with a hydro-pneumatic machine, a deſcription of which may be ſeen in the Memoirs of the Academy of Sciences for the year 1782. By the help of this machine you may aſcertain in a very accurate manner, the quantity of oxygen gas introduced into the balloon, and that conſumed during the courſe of the operation.

109. When every thing is thus arranged, kindle the phoſphorus by means of a burning glaſs; the combuſtion will be exceedingly rapid, and accompanied with a large flame and a ſtrong heat. In proportion as it is effected, there is formed ſuch a quantity of white flakes, which attach themſelves to the inſide of the veſſel, that it is ſoon rendered entirely opake.

---

[*] Eight grammes.

110. When the whole apparatus has cooled, and you have aſcertained the quantity of oxygen gas employed, weigh the balloon again before you open it. Then waſh, dry, and weigh the ſmall quantity of phoſphorus remaining in the cup, in order that it may be deducted from the whole quantity of phoſphorus employed in the experiment, By obſerving theſe precepts, it will be eaſy to determine, 1ſt, The weight of the phoſphorus burnt; 2d, The weight of the oxygen gas which has combined with the phoſphorus; 3d, The weight of the flakes obtained by the combuſtion. This experiment will give nearly the ſame reſults as the preceding.

111. It thence appears that the phoſphorus, in burning, combines itſelf with oxygen equal to one and a half of its own weight; and that the weight of the white flakes, or concrete phoſphoric acid, produced, is equal to the ſum of the weight of the phoſphorus burnt, and that of the oxygen combined with it.

112. In ſuch caſes a great deal of heat is produced, and indeed experiment proves that 0·204 pound * of phoſphorus in burning can diſſolve a little more than 100 pounds of ice. This combination excites therefore above 13000 degrees of heat (332).

113. The combuſtion of phoſphorus ſucceeds alſo in atmoſpheric air, with this difference: 1ſt,

---

* A hectogramme.

That the combuſtion is much leſs rapid, as it is checked by the mephitic part of the air; 2d, That there is only about a fifth of the air abſorbed, the abſorption taking place entirely at the expence of the oxygen gas.

114. The phoſphorus by its combuſtion is transformed therefore into a new ſubſtance, and it acquires properties entirely different. From being inſoluble in water, it not only becomes ſoluble in that fluid, but it attracts the moiſture contained in the air with aſtoniſhing rapidity; and it reſolves into a liquor much denſer than water, and of a ſpecific gravity much greater. The phoſphorus before its combuſtion has ſcarcely any taſte: by its combination with oxygen it acquires a taſte exceedingly ſour and pungent, and becomes what is called an acid: in a word, from the claſs of combuſtible, it paſſes into that of incombuſtible ſubſtances.

115. This convertibility of a combuſtible into an incombuſtible ſubſtance; in a word, into an acid, by the addition of oxygen, is, as we ſhall ſee hereafter (802 *et ſeq.*) a property common to a great number of bodies. In general, therefore, we give the name of *Oxygenation* to the combination of every combuſtible body with oxygen.

116. Sulphur alſo is a combuſtible body, which has the property of decompoſing pure air, and of taking oxygen from caloric. This may be eaſily proved

proved by experiments entirely ſimilar to the preceding (104 *et ſeq*). But it muſt here be obſerved that it is impoſſible, when operating on ſulphur, to obtain reſults ſo accurate as thoſe obtained with phoſphorus; becauſe the acid formed by the combuſtion of ſulphur is difficult to be condenſed; and becauſe the ſulphur itſelf burns with great difficulty, and is ſuſceptible of being diſſolved in different gaſes.

117. But you may aſcertain, after the experiment, that the ſulphur in burning combines with the baſe of pure air; and that the acid which is then formed is much heavier than the ſulphur was, for its weight is equal to the ſum of the weight of the ſulphur and that of the oxygen which has combined with it: this, therefore, ſhews that the acid did not exiſt entirely formed in the ſulphur, as the old chemiſts pretended; in the laſt place, that this acid is ponderous, incombuſtible, and ſuſceptible of combining with water in every proportion: no uncertainty remains but in regard to the quantities of ſulphur and oxygen which conſtitute that acid, called *Sulphuric* or *Sulphurous Acid*, according to the greater or leſs quantity of oxygen combined with it.

118. Carbon, which may be conſidered as a ſimple combuſtible ſubſtance, has alſo the property of decompoſing pure air, and of taking its baſe from caloric. But the acid which reſults from this combuſtion neither condenſes itſelf into a liquor, nor aſ-

ſumes

ſumes the concrete form at that degree of preſſure and temperature in which we live: it remains in the ſtate of an aeriform fluid, and a great quantity of water is required to abſorb it: any given quantity of water can diſſolve only a volume of it nearly equal to its own. This acid has all the properties common to the other acids, but in a much weaker degree; and, like them, it combines with every baſe ſuſceptible of forming neutral ſalts: but it may be expelled from its baſe by all the other acids, even the weakeſt of them.

119. The combuſtion of charcoal may be effected in the ſame manner as that of phoſphorus, under a bell-glaſs A *(fig. 7)* filled with pure air or oxygen gas, and inverted over mercury in a pneumatic apparatus. But as a hot or even ignited wire would not be ſufficient to kindle the charcoal, care muſt be taken to place over it a bit of cotton and a ſmall atom of phoſphorus: the ignited wire readily kindles the phoſphorus, and the inflammation is communicated to the cotton, and then to the charcoal. The details of this experiment may be found in the Memoirs of the Academy of Sciences for the year 1781.

120. It thence reſults, that to ſaturate twenty-eight parts of carbon with oxygen, ſeventy-two parts in weight of the latter are required, and that the aeriform acid produced is perfectly equal in weight to the ſum of the weight of the carbon, and that of the

oxygen

oxygen which ſerved to form it. This aeriform fluid is known at preſent under the name of *Carbonic Acid Gas.*

121. It has been aſcertained by means of the calorimeter (*fig*. 46) that a pound of charcoal, in burning, is capable of diſſolving ninety-ſix pounds ſix ounces of ice. In this operation two pounds, nine ounces, one dram, and ten grains of oxygen combine with the charcoal, and there are formed three pounds, nine ounces, one dram, and ten grains of carbonic acid gas, a cubic inch of which weighs 0·695 grains. The combuſtion of a pound of charcoal * forms therefore 47358 cubic inches, or above 27 cubic feet † of carbonic acid gas.

122. Theſe examples are ſufficient to ſhew that the formation of the acids is effected by the oxygenation of any body whatever. It is here ſeen that oxygen is a principle common to them all; that it is it which occaſions their acidity; and that they are all afterwards diſtinguiſhed from each other by the nature of the acidified ſubſtance, that is, by the nature of their baſe. In every acid we muſt diſcriminate the acidifiable baſe, to which Guyton-Morveau has given the name of *Radical*, and the acidifying principle, which is oxygen.

---

* 489506 milligrammes.

† Above nine hectolitres.

123. There are different degrees of oxygenation. When metallic ſubſtances are heated to a certain degree, oxygen has more affinity for them than it has for caloric. Metallic ſubſtances, therefore, if we except gold, ſilver, and platina, have the property of decompoſing oxygen gas, and of combining with its baſe by diſengaging from it the caloric. This, however, does not convert them into acids; for that purpoſe there is not a ſufficiency of oxygen: it only reduces them to an earthy powder.

124 The old chemiſts gave to theſe earthy powders the name of *Calces*, as they did to every ſubſtance which had been long expoſed to the action of heat without being fuſed. They confounded, therefore, under one denomination, lime-ſtone, which from being a neutral ſalt is converted by calcination into an earthy alkali, loſing half its weight, and the metals, which by the ſame operation combine with a new ſubſtance that adds to their weight. To diſtinguiſh theſe two things, ſo different, we now give the name of *Calx* to calcined lime-ſtones, and that of *Oxides* to metals combined with oxygen, as well as to ſome other ſubſtances combined with a little oxygen.

125. The firſt degree of oxygenation conſtitutes *oxides*: the ſecond conſtitutes *weak acids*, or thoſe the names of which have been made to terminate in *ous*; as the *ſulphurous*, *nitrous*, &c.: the third degree conſtitutes the *ſtrong acids*, ſaturated with oxygen,

gen, the names of which have been made to terminate in *ic*; ſuch as the *nitric* and *ſulphuric* acids, &c.: the fourth degree of oxygenation conſtitutes thoſe which are more than ſaturated with oxygen, and which are called *Oxygenated*; ſuch is the *oxygenated muriatic gas.*

CLASS II.

Of the Suffocating Elaſtic Fluids.

126. Theſe fluids are thoſe which can ſerve neither for reſpiration nor for maintaining combuſtion and animal life. Of this nature are all thoſe gaſes of which we are now going to treat (58). We have divided them into three orders; 1ſt, Thoſe which are not ſaline; 2d, Thoſe which are ſaline; 3d, Thoſe which are inflammable (59).

We ſhall firſt ſpeak of thoſe which are not ſaline (60).

ORDER I.

Non-Saline Gaſes.

127. Theſe gaſes are thoſe which are neither acid nor alkaline (60), ſuch as azotic gas, nitrous gas, and oxygenated muriatic gas.

§. *Azotic Gas.*

128. Azotic or atmoſpheric gas is the non-reſpirable part of the atmoſphere, of which it forms nearly

nearly three-fourths (87). To this fluid Prieſtley gave the name of *Phlogiſticated Air*, becauſe he believed it to be only air altered by the phlogiſton diſengaged from bodies during combuſtion, or from odorous bodies, &c. But it is now fully proved, that this fluid exiſts completely formed in the atmoſphere, and that it remains more or leſs alone, in proportion as the pure air is abſorbed.

129. Azotic gas is compoſed of a baſe called *Azote* (69), combined with caloric. With this baſe we are little acquainted, becauſe it is not poſſible to procure it alone and diſengaged from combination, for it cannot be ſeparated from caloric without fixing it in another body. It has been diſtinguiſhed by the name of *Azote*, which ſignifies a depriver of life, becauſe animals cannot live in this fluid when it is alone and ſeparated from pure or vital air.

130. Azotic gas is the reſiduum of the reſpiration of animals, of the combuſtion of bodies, and of putrefaction; becauſe in all theſe caſes the pure air is either abſorbed or deſtroyed.

131. By the reſpiration of animals pure air is in part decompoſed in their breaſt, as its oxygen combines with the hydrogen which it there finds, in order to form water, and abandons all its caloric: the other portion combines with the carbon carried thither by the veinous blood, and forms carbonic acid gas, abandoning a part of its caloric: theſe two portions

tions of caloric abandoned by the pure air, continually ſerve to repair that loſs of natural heat which animals are every moment ſuſtaining. The pure air being totally employed in theſe two functions, the azotic gas remains alone, and is expired along with the carbonic acid which has been formed (98).

132. During the combuſtion of bodies, a part of the oxygen of the pure air combines with the burning body: another part combines with the carbon furniſhed by the combuſtible body, and forms carbonic acid gas, while the azotic gas remains mixed with the carbonic acid gas which has been formed.

133. In putrefaction, as in combuſtion, a part of the oxygen of the pure air combines with the putrefying body, while another part combines with the carbon furniſhed by the putrid matter, and forms carbonic acid gas; and the azotic gas is found to remain mixed with the carbonic acid gas.

134. It is ſeen, therefore, that in all theſe caſes the azotic gas is found mixed with carbonic acid gas, from which it may be eaſily freed by ſhaking the whole in lime water: the carbonic acid combines with the lime and forms chalk, while the azotic gas remains pure.

135. There are ſeveral methods of obtaining azotic gas pure: the moſt uſual is the proceſs of Scheele, which conſiſts in expoſing a determined

quantity of atmoſpheric air over ſulphuret, or liquid liver of ſulphur under bell-glaſſes: the ſulphuret gradually abſorbs the baſe of the oxygen gas, and, when the abſorption is complete, the azotic gas remains pure. 2d, It may be obtained alſo, according to the diſcovery of Berthollet, by treating muſcular fleſh, or the fibrous part of blood well waſhed, with nitrous acid, in a pneumatic apparatus; becauſe *azote*, the baſe of this gas, is a conſtituent part in the compoſition of fleſh, and ſerves to animalize it: but the animal matters muſt be very freſh; for if they are tainted, they furniſh carbonic acid gas, mixed with azotic gas. 3d, It is extracted from nitre by detonation with ſome combuſtible body; but if the combuſtible body employed be charcoal, the azotic gas is found mixed with carbonic acid gas, from which it may be afterwards freed by means of cauſtic alkali or lime-water. 4th, It is extracted alſo by means of the combination of ammonia with the metallic oxides: in this combination the hydrogen of the ammonia joins the oxygen of the oxide, and forms water; and the azote is diſengaged under a gaſeous form.

136. Azotic gas will be found pure alſo in the reſiduum of air, which has ſerved for the oxidation of metals, as well as in the reſiduum of air which has been mixed in due proportion with nitrous gas (197) becauſe the metals and the nitrous gas combine with the oxygen, the baſe of pure air: after this combination there remains nothing but azotic gas.

137. Fourcroy has diſcovered that the air-bladders of fiſhes are filled with azotic gas, and that to collect it, nothing is neceſſary but to burſt theſe bladders under bells filled with water.

138. Azotic gas is ſomewhat lighter than atmoſpheric air: its ſpecific gravity is to that of air as 96·31 is to 100, and to that of diſtilled water as 11·9048 is to 10000; ſo that the cubic inch of this fluid weighs 0 4444 of a grain; and the cubic foot 1 ounce, 2 drams, 48 grains *.

139. Azotic gas, when pure, has no ſenſible odour or taſte.

140. It is not ſoluble, or at leaſt very little ſo, in water. This may be proved by putting into a long glaſs tube (*fig.* 9) divided into equal parts by ſcratches made with a diamond, three or four meaſures of this gas, and then ſtrongly ſhaking the tube in water with its aperture downward: its volume will not be ſenſibly diminiſhed.

1. Azotic gas gives no ſign of acidity: it does not redden blue vegetable colours, as all the acids do, nor does it precipitate lime from a ſolution of it in water.

---

* According to the new ſyſtem of meaſures, a cubic decimetre of this gas weighs 1 gramme, 190 milligrammes; and the cubic metre 1 chiliogramme, 190 grammes, and 64 milligrammes.

142. Azotic gas ſuddenly extinguiſhes burning bodies, and ſuffocates ſpeedily and with great energy animals immerſed in it.

143. Azotic gas becomes reſpirable by the vegetation of green plants, becauſe theſe vegetables occaſion a production of pure air, as they abſorb the hydrogen of the water, which becoming decompoſed, ſerves for vegetation, and by theſe means leaves free the oxygen, which, combining with caloric, forms pure air. If to 72 parts of azotic gas you add 28 parts of pure air, you will form an air ſimilar to that of the atmoſphere, and, like it, reſpirable (87).

144. *Azote*, the baſe of the azotic fluid, is one of thoſe principles moſt abundantly diffuſed throughout nature. When combined with caloric it forms azotic gas (129) which always remains under a gaſeous form, and which makes about three-fourths of the fluid that we reſpire; combined with hydrogen, it forms ammonia (847); with oxygen it forms either nitrous oxide, the baſe of nitrous gas (70) or the nitrous or nitric acid (806) according to the degree of oxygenation: combined with carbon, phoſphorus, or ſulphur, it forms *azoturets*; for theſe three ſubſtances are ſuſceptible of being diſſolved in azotic gas.

145. *Azote* is one of the elements alſo which conſtitute animal matters: it is there combined with carbon and hydrogen, and ſometimes with phoſphorus;

phorus; the whole are connected by a certain portion of oxygen, which reduces them to the ſtate of oxide, or even of acid, according to the degree of oxygenation. The nature of animal matters may therefore vary, like that of vegetable matters (1003 *et ſeq.)* three ways: 1ſt, In regard to the number of the ſubſtances which enter into the combination of the radical; 2d, In regard to the proportion of each of theſe ſubſtances; 3d, In regard to the degree of oxygenation.

146. We have every reaſon to believe that *azote* is a ſimple and elementary ſubſtance; at any rate it has never yet been decompoſed: and this circumſtance is ſufficient to induce us to conſider it as an element.

Having analyſed the two ſubſtances which eſſentially conſtitute atmoſpheric air, it will now be proper to examine what are the phyſical properties of that air in which we live.

Of the Phyſical Properties of Atmoſpheric Air.

147. We have already (85) ſhewn that atmoſpheric air is a mixture of two elaſtic fluids, one of which is pure air or oxygen gas (89) and the other azotic gas (128). The firſt of theſe fluids is the only one proper for maintaining animal life (98) and the combuſtion of bodies (100); by the ſecond, if alone, we ſhould ſpeedily be ſuffocated; and burning bodies

immerſed in it would ſuddenly be extinguiſhed (142). The firſt, indeed, were we to reſpire it alone and without mixture, would ſoon put a period to our exiſtence by the ardent heat which it would communicate to our whole frame (99). We have reaſon, therefore, to admire the wiſdom of Providence in the compoſition and mixture of that fluid, which has been given to us for the purpoſe of reſpiration. This air, ſo pure and ſo proper for maintaining life, may be compared to ſpirituous liquors, which are good of themſelves, but muſt be uſed with moderation.

148. The air everywhere ſurrounds the globe of the earth, and, in ſome meaſure, ſerves it as a covering. This covering is what is called the *Atmoſphere.* We ought, therefore, to conſider the air under two different points of view: 1ſt, In itſelf; 2d, As forming the atmoſphere. In the laſt quality, air has properties which it does not poſſeſs when we conſider only a portion of it, and abſtract what foreign matters are mixed with it.

Of Air, conſidered in itſelf.

149. Air, like all other permanent fluids of the ſame kind (56), is heavy, compreſſible, elaſtic, tranſparent, colourleſs, inviſible, and cannot be condenſed into a liquid by cold.

150. Air never becomes a conſtituent part of any body; but its baſes (68 and 69) *viz.* oxygen and azote, enter into the compoſition of a great number of bodies: oxygen enters into the compoſition of all the oxides, all the acids, &c.: and azote into that of animals, that of ſome vegetables, that of the nitrous oxides and acids, that of ammonia, &c. provided theſe baſes ceaſe to be combined with caloric.

151. While theſe baſes remain combined with caloric, they form a fluid which always retains that ſtate: this conſtant fluidity is occaſioned by elaſticity, which continually tends to dilate the maſs, and which preſerves the reſpective mobility of its parts.

152. Air adheres with great force to the ſurfaces of bodies.

153. Air is a *heavy* fluid, and its ſpecific gravity is to that of diſtilled water as 1 to 809, from which we may conclude that a cubic inch of air weighs 0·4601 grain; and a cubic foot, 1 ounce, 3 drams, 3 grains*.

154. Air is a *compreſſible* fluid: it is compreſſed by its own weight, and by every force which acts upon it. But what is the relation which exiſts between

---

* According to the new ſyſtem, a litre of air weighs one gramme, 232 milligrammes; and the chiliolitre or cubic metre, weighs 1 chiliogramme, 231 grammes, 903 milligrammes.

tween the condenſation of the air and the compreſſing force? It is proved by experiment, that *compreſſed air decreaſes in volume in the ſame ratio as that in which the compreſſing force is increaſed*; from which we conclude, that *the air is condenſed in the direct ratio of the weight with which it is charged.*

155. Air is an *elaſtic* fluid, and its elaſticity always tends to dilate its maſs.

156. The elaſticity of air is perfect; that is to ſay, when the force which compreſſes air ceaſes to act, it recovers its former ſtate, 1ſt, Completely; 2d, With the ſame promptitude as that with which it was compreſſed.

157. The elaſticity of the air is alſo *unalterable:* the ſpring of the air is in no manner changed, either by the force or continuance of compreſſion. Roberval found that a maſs of air which had remained in a ſtate of compreſſion for fifteen years, retained as much elaſtic force at the end of that long period as it would have poſſeſſed a moment after its compreſſion.

158. The ſpring of the air increaſes as its denſity, and in the ſame ratio; ſo that *the ſpring of the air is always equal to and in equilibrium with the compreſſing force*; and by its reaction, it is capable of producing the ſame effect as would be produced by that power.

159. Heat applied to a maſs of air, produces on it one of the two following effects: 1ſt, It increaſes its volume, if that volume is at liberty to be extended; 2d, If the volume of the air cannot extend itſelf; if it be checked by any obſtacles, the heat increaſes its ſpring in proportion as the force which confines the air is greater.

160. Atmoſpheric air is not only a fluid eſſentially neceſſary to maintain animal life, but is more particularly appropriated for that function. We have already proved (85) that atmoſpheric air is compoſed of one part of a fluid eſſential to the reſpiration of man and other animals, and of three parts of a mephitic air, which, if alone, would be capable of ſuffocating them. We have ſhewn alſo (99) that this fluid, eſſential to reſpiration and life, if alone, might deſtroy our exiſtence by furniſhing too much caloric, and occaſioning an inflammation of the lungs. But its activity is moderated by the mephitic air or azotic gas, the baſe of which performs another function, for it enters into the compoſition of fleſh, and ſerves to animalize it (135). *Atmoſpheric air, therefore, is the fluid beſt fitted for maintaining the life of man and of animals.*

161. Atmoſpheric air, and, in particular, pure air, which forms a part of it, is eſſentially neceſſary for the combuſtion of bodies; ſo that the moſt combuſtible matters cannot inflame unleſs in contact with air; and thoſe already inflamed are ſpeedily extin-

extinguiſhed if deprived of it. The reaſon of this is, as before ſaid (100) that combuſtion is nothing elſe than the combination of oxygen, the baſe of pure air, with the combuſtible body. If this oxygen, therefore, be wanting, combuſtion cannot take place.

Of Air, conſidered as the Atmoſphere of the Earth.

162. In whatever ſituation we may be placed, we are always immerſed in air, without which it would be impoſſible for us to exiſt (147); the earth, therefore, is everywhere enveloped in air. To this covering, which preſſes on the earth, and which is carried round with it in its diurnal and annual motion, we give the name of the *Terreſtrial Atmoſphere*.

163. The atmoſphere is a fluid, mixed with a great quantity of foreign ſubſtances. Of this we may be fully convinced, merely by reaſoning; for as nothing that has been created is annihilated, it is evident that every thing which is diſſipated and diſappears paſſes into the atmoſphere; and as we do not meet with the ſame ſubſtances at all times and in all places, its ſtate muſt vary according to time and place.

164. The atmoſphere may be conſidered under two points of view: 1ſt, As a fluid at reſt, or, at leaſt

leaſt reſpectively ſo to us; 2d, As an agitated fluid.

The Atmoſphere, conſidered as a Fluid at Reſt.

165. We have already ſaid (153) that air is a heavy fluid; but the atmoſphere is compoſed of air, and therefore the *atmoſphere is heavy*. But its weight is that of a fluid, and conſequently it muſt increaſe or decreaſe according to the perpendicular height of the columns, and according to the breadth of their baſes. It is, indeed, according to theſe proportions that it acts on the earth and on us, as has been proved by experiments.

166. It would be gratifying to curioſity to be able to determine the height of the atmoſphere; but this is exceedingly difficult, if not impoſſible. The weight of a column of our air would give us that height, were the air of the atmoſphere of the ſame denſity throughout its whole extent; or, at any rate, if we could aſcertain by what progreſſion the air dilates itſelf in proportion to its diſtance from the earth, and to its being leſs charged by the ſuperincumbent ſtrata. But this knowledge we have never yet been able to obtain, or, at leaſt, we have obtained it only in regard to the lower part of the column; and, even in that caſe, we approach only near the truth.

167. De la Hire, in conſequence of an idea of Kepler, was induced to employ the crepuſculum, or

or twilight, for determining this point, of ſo much importance. Aſtronomers agree that the twilight begins and ends when the ſun is depreſſed 18 degrees below the horizon, reckoning theſe degrees on a vertical circle. The ſolar rays then touch in an oblique direction the upper ſurface of the atmoſphere, and being there refracted, proceed thence to the earth. Were the atmoſphere of leſs height than it is, the twilight would not commence till the depreſſion of the ſun below the horizon were leſs than 18 degrees; and if it were higher, the twilight would begin at a greater depreſſion of the ſun below the horizon than 18 degrees. There is therefore a neceſſary relation between the duration of the twilight and the height of the atmoſphere. From reſearches made in regard to this relation, De la Hire concluded, and with ſome degree of probability, that the height of the atmoſphere is about 16 leagues. There is reaſon, however, to ſuppoſe that the air extends to a much greater height; but that beyond 16 leagues, it has too little denſity to be able to refract the light in a ſenſible manner.

168. The weight of a column of air, as indicated by the barometer, enables us to aſcertain the weight of the atmoſphere on a given ſurface; and, by theſe means, we can determine the preſſure of the air on our bodies. This preſſure is equal to that of a column of mercury having the ſame height as that of the mercury in the tube of the barometer, and a baſe equal to the ſurface of the body, which is enormous,

mous, ſince it is equal to the weight of 30,000 pounds. We, however, are not ſenſible of it, becauſe we reſpire the ſame fluid as that to the preſſure of which we are expoſed, and becauſe this preſſure cauſes a continual ſenſation; and, it is well known, that it is only things with which we are not habituated that make an impreſſion on our ſenſes.

169. We have already ſaid (163) that the air contains a great many foreign ſubſtances, different in their nature, which ariſe from the earth. Theſe ſubſtances we divide into two claſſes: the firſt comprehends all thoſe which in their nature approach to water, and which are called *Vapours*; the ſecond includes the ſaline, fat, ſpirituous, &c. matters to which we give the name of *Exhalations*. All theſe ſubſtances, differently mixed or modified, aſſume different forms, and produce different phenomena, called *Meteors*.

170. Meteors then are phenomena which take place in the atmoſphere. They are divided into three kinds: *aqueous*, *luminous*, and *fiery meteors*.

171. Aqueous meteors are produced by the water contained in the atmoſphere, either in the ſtate of vapour, or in ſolution. Such are the *evening* and *morning dew*, *fogs*, *clouds*, *rain*, *ſnow*, *hail*, &c.

172. The luminous meteors are thoſe which exhibit the priſmatic colours by the decompoſition of light. Of this kind are the *rainbow*, *crowns*, &c.

173. Fiery

173. Fiery meteors are thoſe which occaſion inflammation or combuſtion in the atmoſphere; as *lightning*, *thunder*, *fire-balls*, the *aurora borealis*, &c.

The Atmoſphere, conſidered as an Agitated Fluid.

174. In the air of the atmoſphere two kinds of movement are obſerved. One is merely a tremulous or vibratory movement, communicated to the parts of this fluid, and which agitates them for ſome time without diſplacing them. It is this movement which conveys ſound. The other is a real movement of tranſlation, by which a conſiderable portion of the atmoſphere is impelled from one place to another, with a greater or leſs velocity, and in one determinate direction. This movement produces the wind.

Of Sound.

175. Sound is occaſioned by a vibratory motion excited in a ſonorous body, in conſequence of the impulſe of another body, and communicated afterwards by the ſonorous body to the fluid which ſurrounds it, and tranſmitted by the latter to the ear, the organ deſtined to receive its impreſſion.

176. From this definition, it follows that ſound ought to be conſidered under three different points of view: 1ſt, In the ſonorous body which gives birth

to it; 2d, In the medium which tranſmits it; 3d, In the organ which receives the impreſſion.

177. That bodies may be ſonorous, it is neceſſary they ſhould be elaſtic; and their ſound in regard to duration, intenſity, or force, is proportioned to their vibrations.

178. We cannot be ſenſible of the motion of bodies which are at ſome diſtance, but by means of a medium capable of tranſmitting that movement to us. Without ſuch a medium, therefore, we ſhould have no perception of the vibrations of a ſonorous body. Elaſtic fluids are the mediums beſt fitted for that purpoſe.

179. Air is the moſt common medium through which ſound tranſmits itſelf; and it is conveyed and extended to a greater diſtance in proportion to the greater denſity of the fluid through which it is propagated. Sound is tranſmitted alſo by liquors; for, though they are not very elaſtic, they are not altogether deſtitute of ſpring. Sound may be tranſmitted alſo by ſolid bodies, provided they have the neceſſary degree of elaſticity.

180. When ſound meets with obſtacles, it changes its direction, and is reflected. This is what cauſes echoes, which never take place in plains. To produce an echo, it is neceſſary that there ſhould be ſome objects elevated above the level country.

No echoes, therefore, are heard at ſea, nor in plains where there are neither trees nor houſes; but they are very common in the woods, in valleys, oppoſite to rocks, on mountains, &c.

181. The ear is the organ deſtined to receive ſounds: hearing then is a ſenſation excited in us by ſounds received into the ear. The ſound firſt reaches the exterior part of the ear, having the form of a funnel, in order to favour the entrance of a greater quantity of the ſonorous radii, which through the *meatus auditorius*, are conveyed to the tympanum; and thence tranſmitted to every internal part of the ear. Theſe ſenſations are afterwards conveyed to the ſenſorium of the brain, by means of the auditory nerve, which is divided into ſeveral branches, ſubdivided into ſmall fibres, and diſtributed to every part of the ear.

Of the Winds.

182. Wind is a movement of the air, by which a certain portion of the atmoſphere is impelled from one place to another, with a greater or leſs velocity, and in a determinate direction. It is from this direction that names given to the winds are deduced; for they are diſtinguiſhed by different appellations, according to the different points of the horizon from which they blow.

183. The winds are divided into general and conſtant, periodical or regular, and variable winds. General winds are thoſe which always blow from the ſame quarter: ſuch are the *trade-winds*, which prevail between the tropics, eſpecially in the open ocean, and which conſtantly blow from eaſt to weſt, with ſmall variations, occaſioned by the changes in the ſun's declination.

184. The periodical or regular winds, are thoſe which blow periodically from one point of the horizon at one ſeaſon, and from a different point at another: of this kind are the *monſoons*, ſuch as thoſe which blow from the ſouth-eaſt between October and May, and from the north-eaſt between May and October, near the coaſt of Zanguebar and the iſland of Madagaſcar.

185. The variable winds are thoſe which blow ſometimes from one quarter, and ſometimes from another; which begin and ceaſe without being ſubject to any rule in regard to time or place, and which vary in their duration, direction, and velocity. Such are thoſe which prevail at London, and in many other parts of Europe.

186. The winds are occaſioned, in general, by the equilibrium of the air being deſtroyed; ſo that thoſe parts which have the greateſt force proceed to that quarter in which they find the leaſt reſiſtance. But what is the cauſe by which this equilibrium is deſtroyed?

Our knowledge on this ſubject is very imperfect. In my opinion, electricity, which, as is well known, prevails in the atmoſphere and at the ſurface of the earth, ought to be conſidered as the firſt and general cauſe of winds, rather than thoſe cauſes aſſigned by philoſophers, ſome of which are vague, and far from being ſatisfactory.

187. The principal things to be conſidered in regard to the wind, are its direction, its velocity, and its force. Its direction is determined by the point of the horizon from which it blows. Its velocity is exceedingly variable; and different means have been deviſed for meaſuring it. The force of the wind depends upon its velocity, and the maſs of the air which it cauſes to act againſt the obſtacle that oppoſes it. The ſame wind, therefore, makes a greater effort according as the ſurface of the obſtacle preſented to it is more extenſive.

188. Great advantages are derived from the winds, by making them produce effects which would require the force of a great many men or animals: they ſerve to give motion to mills employed for grinding corn, for bruiſing fruits and ſeeds to extract oil from them, for fulling cloth, &c.; they convey ſhips from one ſhore of the ocean to another; which could not be done but with difficulty and great expence, by the force of oars *.

---

* For further details reſpecting the phyſical properties of the air, ſee my *Principes de Phyſique*, from Art. 886 to Art. 1039, incluſively.

Continuation of the Suffocating Elaſtic Fluids.

4. *Nitrous Gas.*

189. Nitrous gas was diſcovered by Hales; but Prieſtley made known the greater part of its properties. It does not exiſt in a natural ſtate, and muſt be obtained by the aſſiſtance of art. It is one of the conſtituent parts of the nitrous acid; and it would be nitrous acid itſelf were it not deprived of a large portion of its oxygen, which makes it ceaſe to be an acid. It is compoſed with the ſame baſe as that of the nitrous acid, which is azote (70) holding in a ſtate of gas two parts of oxygen; that baſe being combined with caloric. In this ſtate it is not ſoluble in water; but if you furniſh it with a third part of oxygen, by combining with that exceſs, it becomes acid, and very ſoluble in water. If in one part therefore of azote there are only two parts of oxygen, it is merely a nitrous oxide, which is the baſe of nitrous gas; if there are three parts of oxygen, it forms fuming nitrous acid; if there be four parts, the reſult is white nitric acid. Theſe two laſt compounds are acid, and perfectly ſoluble in water: the firſt is neither acid nor ſoluble.

190. It may be eaſily ſhewn, both by analyſis and ſynthesis, that the baſe of the nitrous acid is azote combined with oxygen, but not to ſaturation, which

would make it nitric acid. 1ſt, By analyſis. Nitrous acid may be decompoſed by making it act on ſome metal (copper, for example) which takes from it a part of its oxygen, and reduces it to the ſtate of nitrous gas; if you then expoſe this nitrous gas over an alkaline ſulphuret which will deprive it of the reſt of its oxygen, nothing will remain but azotic gas, therefore, &c. 2d, By ſyntheſis. Mr. Cavendiſh formed nitrous acid by expoſing ſeven parts of pure air and three of azotic gas to the action of the electric fluid; the azote combined with the oxygen of the pure air, and the reſult was nitrous acid: the baſe of nitrous gas therefore is azote combined with oxygen.

191. Nitrous gas therefore may be obtained from the nitrous or nitric acid, made to act on combuſtible matters. Theſe matters combine with a greater or leſs portion of the oxygen of the acid, while the azote, which retains a part of the oxygen by combining with caloric, forms nitrous gas, which paſſes into the bell placed to receive it. The ſubſtances proper for this purpoſe are iron, copper, braſs, tin, ſilver, mercury, biſmuth, and nickel. It may be extracted alſo by means of gold and antimony from the nitric acid, which makes a component part in the nitro-muriatic acid employed to diſſolve theſe metals. It may be extracted alſo from the nitrous acid, by making it to act on alcohol, ether, oils, reſins, gums, charcoal, ſugar, &c.

192. By whatever ſubſtance extracted, its properties are the ſame; but it is obtained in the greateſt quantity by means of metals. There are ſome, however, by means of which you extract only azotic gas, becauſe they ſeize on all the oxygen of the nitrous acid employed. The flaſk made uſe of to cauſe the acid exerciſe an action on the metal ought to be entirely filled with the former, becauſe if any air were left in it, the gas in diſengaging itſelf would combine with the oxygen of the pure air, and this combination diſſolving in the liquor, would occaſion a vacuum which would permit the water of the tub to paſs into the flaſk.

193. Nitrous gas is a little heavier than atmoſpheric air: its ſpecific gravity is to that of air as 105·35 is to 100, and to that of diſtilled water as 13·0179 is to 10000. A cubic inch of this fluid weighs 0·4860; and the cubic foot 1 ounce 3 drams 48 grains *.

194. Nitrous gas, when very pure, is not ſoluble in water; as may be eaſily proved by agitating it in that liquid.

195. It gives no ſign of acidity, as it does not redden blue vegetable colours; nor does it combine with alkalies unleſs it be mixed with air, for it then becomes acid by ſeizing on the oxygen of the air.

---

* According to the new French ſyſtem, a cubic decimetre of this fluid weighs 1 gramme 301 milligrammes; and the cubic metre 1 chiliogramme 301 grammes 335 milligrammes.

196. Nitrous gas ſpeedily deſtroys plants and animals immerſed in it; and it extinguiſhes burning bodies, firſt making the flame aſſume a green colour.

197. If nitrous gas be mixed with atmoſpheric air, it becomes red, and has the odour of nitrous acid; as may be eaſily proved by diffuſing a little of it through the air: it then abſorbs the oxygen of the air, combines with it, and becomes nitrous acid. This may be better ſhewn by the following experiment: Put two meaſures of atmoſpheric air and then one of nitrous gas into a glaſs tube (*fig.* 9) marked in equal diviſions with a diamond: the mixture will immediately become red and grow hot; and as this combination, which is really nitrous acid, is very ſoluble in water (189) you will ſee the water aſcend in the tube in proportion as the mixture diſſolves in it, ſo that of the 3 meaſures about 1½ will be diſſolved, if the air be of a good quality. What remains under the gaſeous form is nothing but azotic gas. The heat produced on this occaſion, is owing to the caloric of theſe fluids, which aſſumes the free ſtate. If, inſtead of atmoſpheric air, you mix pure air with the nitrous gas, *viz.* two meaſures of gas and one of pure air, the redneſs will be much more intenſe, the heat produced far greater, and the mixture will be almoſt entirely diſſolved in the water.

198. It may be here ſeen, that by means of this gas, we can aſcertain the ſalubrity of the air; for it combines only with oxygen or the baſe of pure air, which is the only reſpirable part of the atmoſphere. Air ſubjected to this teſt, ought therefore to be conſidered as ſo much fitter for reſpiration, according as the quantity of it abſorbed is greater.

199. The water in which this mixture of nitrous gas and pure air is diſſolved, becomes liquid nitrous acid; ſo much the ſtronger the leſs it contains of water. 1ſt, It reddens blue vegetable colours: it is therefore acid; 2d, This acid unites and combines with alkalies, and forms with them detonating nitres: it is therefore nitrous acid. To prove this, affix to the bottom of a bell glaſs (*fig.* 10) ſome concrete carbonate of ammonia tied up in a ſmall piece of gauze, and place the bell on the ſhelf E F (*fig.* 4) of a pneumatic tub in ſuch a manner that the bell may be two-thirds filled with atmoſpheric air, while the other third contains water. If you then make nitrous gas to paſs into the bell, the mixture will immediately aſſume a red colour (197): an effect produced by the combination of the gas with the reſpirable part of the air. By this combination the gas has become nitrous acid. You will then perceive a great deal of white vapours ariſing from the combination of this acid with the carbonate of ammonia. Theſe vapours are afterwards condenſed, and cryſtallize. The cryſtals col-

ected will fuſe on burning coals, and therefore are nitre.

5. *Oxygenated Muriatic Gas.*

200. Oxygenated muriatic gas, the dephlogiſticated muriatic acid of Scheele under a gaſeous form, is the muriatic acid gas of which we ſhall ſpeak hereafter (229 *et ſeq.*) but ſurcharged with oxygen, and perfectly dephlegmated (71).

201. This gas is obtained by expoſing the muriatic acid to heat and evaporation while it is acting on a ſubſtance that contains oxygen; ſuch, for example, as the native oxide of manganeſe. If you therefore put 50 parts of the native oxide of manganeſe and 100 parts of muriatic acid into a glaſs retort (*fig.* 12) and expoſe it to heat, a ſtrong fermentation will be excited, during which the muriatic acid will be converted into gas, but ſurcharged with oxygen which it takes from the oxide of manganeſe, becauſe it has a great affinity for that ſubſtance. To collect this gas, when you have reaſon to think that all the air in the retort has paſſed over, introduce the beak of it below a bell filled with mercury or water; for this gas does not diſſolve in water but in a ſmall quantity, and when the water is ſaturated with it, the exceſs of the gas will paſs into the upper part of the bell.

202. This gas then is compoſed of muriatic acid gas (229) and an exceſs of oxygen. It is this oxygen in exceſs which, though it be the acidifying principle, deprives it of the whole, or nearly the whole, of its acidity, and renders it leſs ſoluble in water. This is a fact difficult to be explained. We have already ſaid (197 *et ſeq.*) that an exceſs of oxygen added to nitrous gas, produces in it a contrary effect; for it gives it an acidity it did not before poſſeſs, and renders it perfectly ſoluble in water. It would be difficult to account for theſe different effects, but they are facts well atteſted, which we ought to adopt though ignorant of the cauſe.

203. Oxygenated muriatic gas is not inviſible like the other gaſes; it is of a greeniſh-yellow colour, which renders it very perceptible. It has a ſtrong pungent odour, and is dangerous to inſpire, becauſe it excites a violent cough, and might occaſion a hæmorrhage.

204. We have before mentioned (202) that oxygenated muriatic gas is not acid, or, at leaſt very little ſo: a proof of this is, that it does not combine or at leaſt very little with alkalies, and that it has not force ſufficient to drive the carbonic acid from the different baſes with which it is combined: an effect produced by all the known acids, however weak; beſides, it does not redden blue vegetable colours, as it would do if it were acid. It

however deſtroys not only blue, but alſo all the other vegetable colours, and converts them into white. It deprives all flowers of their colour, and bleaches cloth, yellow wax, ſilk, &c. It is by means of its exceſs of oxygen that it produces theſe effects; and by loſing its exceſs of oxygen it returns to the ſtate of ſimple muriatic acid gas, which is then entirely ſoluble in water.

205. Oxygenated muriatic gas extinguiſhes burning bodies, and ſpeedily deſtroys animals immerſed in it.

206. This gas has the property of decompoſing ammonia: its exceſs of oxygen combines with the hydrogen of the ammonia (which is compoſed of one part of hydrogen and ſix of azote) and forms water, while the azote is left free.

207. Oxygenated muriatic gas is not ſo ſoluble in water as the plain muriatic acid gas, which can in no manner be collected over water: it is however ſoluble in it to a certain degree (201) and then forms liquid *oxygenated muriate*, which is the real ſolvent of gold, platina, &c. as may be proved by putting into that liquor ſome gold leaf, which will be ſpeedily diſſolved.

208. In the nitro-muriatic acid it is the agent that diſſolves gold, for that acid is a mixture of

muriatic acid and nitric acid. In this mixture, the muriatic acid, the radical of which has a great affinity for oxygen, combines with the oxygen of the nitric acid, and, by theſe means, becomes oxygenated muriate (807) and the baſe of the nitric acid remains free; ſo that in this liquor no more acid perhaps is left. The nitric acid has loſt its acidity by loſing its oxygen, and the muriatic acid has loſt its acidity by combining with the oxygen of the nitric acid. Theſe are two facts which, as already ſaid (202) are difficult to be explained.

209. The oxygenated muriate is gradually decompoſed by the contact of light which diſengages its exceſs of oxygen. By loſing this exceſs of oxygen it paſſes to the ſtate of pure muriatic acid; and the oxygen thus diſengaged combining with caloric, forms pure air, called *Oxygen Gas.*

ORDER II.

Saline Gaſes.

210. Theſe gaſes are thoſe which are either acid or alkaline (61); of the latter there is only one found in a natural ſtate; all the reſt are the production of art.

6. *Carbonic Acid Gas.*

211. Carbonic acid gas, of all the gaſes, is that earlieſt known. Paracelſus and the old chemiſts called it the *ſavage ſpirit*, *ſpiritus ſylveſtris*. Van Helmont gave it the name of *ſavage gas*, *gas ſylveſtre*. Afterwards it was called *fixed air* by Boyle, Hales, Black, Prieſtley, Lavoiſier, &c. *mephitic acid* by Bewley; *mephitic gas* by Macquer; and *aerian acid* by Bergman. In the laſt place, Fourcroy called it *chalky acid gas*; and Lavoiſier *carbonic acid gas*, becauſe it is compoſed of oxygen combined with a carbonaceous matter which it holds in ſolution (72) and in the proportion of about 72 parts of oxygen and 28 parts of carbonaceous matter, called by the modern chemiſts *Carbon*.

212. This gas may be obtained in the following manner: Put into a bell glaſs filled with pure air and depoſited over a mercurial pneumatic apparatus, a ſmall veſſel containing a certain quantity of charcoal which has been deprived of its hydrogen gas by calcination in a cloſe veſſel; on this charcoal place one-fourth grain of tinder and a very ſmall bit of phoſphorus; kindle the phoſphorus with a bent wire made red hot and introduced through the mercury: the inflammation of the whole will be exceedingly rapid, and accompanied with a ſtrong light.

light. You will then find in the bell carbonic acid gas, the weight of which will be equal to that of the pure air employed, *plus* the weight loſt by the charcoal. This may be proved by introducing below the bell a known weight of liquid cauſtic alkali, which will abſorb the carbonic acid gas formed during the combuſtion, and the weight of the alkali will be increaſed by a quantity equal to the weight of the carbonic acid above mentioned.

213. In this operation the oxygen, which by its combination with caloric formed pure air, combines with the carbon* and a portion of the caloric, and forms carbonic acid gas; the remainder of the caloric is diſengaged, and, accompanied with heat and light, aſſumes a ſtate of freedom. In this caſe there is indeed too much caloric; for the carbonic acid, to aſſume the gaſeous form, has no need of ſo large a quantity of caloric as pure air has.

214. Carbonic acid is found in a natural ſtate in ſome caverns, in the galleries of mines, and in different ſprings; it is this gas which renders the water of ſome ſprings ſpirituous and acidulous. Of this kind are the waters of Pyrmont, Saint-Mion, Seltz, Pougues, Chateldon, Buſſang, the Spa, &c.

---

* Common charcoal is compoſed of an earthy baſe and a carbonaceous ſubſtance, called by the modern chemiſts *Carbon*. This carbon only is ſoluble in certain gaſes, and the earthy baſe is what forms the aſhes after the combuſtion of the charcoal.

215. Carbonic acid gas is furniſhed in abundance, 1ſt, By ſpirituous liquors in a ſtate of fermentation; as wine, beer, &c. Its formation in this caſe is owing to a combination of the carbonaceous matter of the ſaccharine part with the oxygen principle of the water: 2d, By the reſpiration of man and of animals; for during this proceſs a portion of the oxygen of the air combines with a carbonaceous matter, which, according to the modern chemiſts, is diſengaged from the blood and the lungs, giving up a portion of its caloric to maintain life (98): 3d, By the combuſtion of bodies, during which a part of the oxygen of the pure air combines with the carbonaceous matter of the burning body.

216. The baſe of carbonic acid gas is combined in a great number of natural bodies, ſuch as the carbonate of lime, marble, all kinds of lime-ſtone, the alkaline carbonates, and in general in all natural ſubſtances which effervеſce with acids. It is eaſy to extract it from theſe ſubſtances, if you introduce them into a flaſk A, having two tubulures (*fig.* 11) and furniſhed with a funnel E, and a bent tube B C D, and pour over them nitric or ſulphuric acid diluted with water, becauſe the carbonic acid has ſo little affinity for its baſes, that it is driven from them by every other acid, and ſometimes even by heat.

217. Carbonic acid gas is ſoluble in water, but in ſmall quantity, and the water diſſolves more or leſs of it according to its degree of heat, or rather its de-

gree of cold: the colder it is, the more it diſſolves: but even in that caſe it can only diſſolve a volume equal to about its own.

218. Water which holds carbonic acid gas in ſolution has an acidulous taſte, and poſſeſſes the ſame properties as thoſe mineral waters which are merely gaſeous. This water is really acid, for it reddens tincture of turnſole, and precipitates lime from its ſolution in water. The gas itſelf produces the ſame effects: in combining with the lime it forms carbonate of lime, known under the name of *Chalk*, which is not ſoluble in water: this is the reaſon why it is precipitated. Lime-water, therefore, is a teſt proper for detecting this acid gas.

219. Lime diſſolved in water is precipitated alſo by the fluid expired by animals: this may be eaſily proved; for if you breathe through a tube into a glaſs containing lime-water, in ſuch a manner as to make the breath paſs through the water, you will ſee the lime precipitated.

220. Carbonic acid gas, therefore, is formed in the breaſt, as we have already ſaid (98) by the combination of the oxygen of the air with the carbonaceous matter diſengaged from the blood in the lungs; and this gas is afterwards expired with azotic gas (128).

221. Carbonic acid gas combines with alkalies, and makes them cryſtallize, by forming with them neutral ſalts. To perform this experiment, put a little pure liquid cauſtic alkali into a bottle filled with this gas, and cloſe the mouth of it by means of a moiſtened bladder; if you then extend the alkali well over its ſides, there will be a diminution of its volume, owing to the gas being abſorbed by the alkali, which will be proved by the depreſſion of the bladder: heat, occaſioned by the caloric of the gas becoming free, will be excited during the combination, and on the ſides of the bottle you will ſoon after obſerve cryſtals, which ſtill become larger.

222. Carbonic acid gas is heavier than atmoſpheric air. Its ſpecific gravity is to that of air as 150·60 is to 100, and to that of diſtilled water as 18·6161 is to 10000. A cubic inch of this gas weighs 0·6950 of a grain; and the cubic foot 2 ounces, 0 drams, 48·96 grains *. That it is heavier than atmoſpheric air may be proved by pouring carbonic acid gas, as you would water, into a veſſel full of air; the gas being heavieſt, will diſplace the air, and force it to iſſue from the veſſel: it may be proved alſo by immerſing in the veſſel a lighted taper or a live animal. The taper will be extinguiſhed, and the animal will be ſpeedily ſuffocated; neither of which would have been the caſe had the veſſel remained full of air.

---

* According to the new ſyſtem, a cubic decimetre of this fluid weighs 1 gramme, 861 milligrammes; and the cubic metre, 1 chiliogramme, 860 grammes, 963 milligrammes.

223. Carbonic acid gas, therefore, extinguiſhes burning bodies, and ſuffocates animals.

224. The living beings which periſh ſooneſt in this gas, are thoſe that have two ventricles in the heart; ſuch as man, quadrupeds, cetaceous animals, and birds: a few minutes are ſufficient to deſtroy them without a poſſibility of their being revived. But frogs, ſerpents, fiſhes, inſects, &c. though they ſeem to all appearance dead, after remaining immerſed in it for ſome time, may be recalled to life by expoſing them to the open air. I have kept fiſhes immerſed in this gas for half an hour, and at the end of that period they ſeemed abſolutely lifeleſs; but I have afterwards revived them, by expoſure to the free air, as they were only in a ſtate of aſphyxy. They were however reſtored to life much ſooner by being plunged into water immediately after they were taken from the gas: at the end of two minutes they were as lively as before being immerſed in it. The water no doubt abſorbs the gas by which they are ſuffocated (217) and renders them fit for receiving freſh air. If perſons in a ſtate of aſphyxy could be immerſed in water without being ſuffocated, it might perhaps be the ſpeedieſt means of curing them.

225. Several philoſophers are of opinion that carbonic acid gas has the property of preſerving animal ſubſtances, and of retarding their putrefaction; which I can readily believe, becauſe the preſence of pure air (89) or at leaſt of a ſubſtance capable of

furniſhing oxygen, ſuch as water, is neceſſary to putrefaction; for bodies do not putrefy but in conſequence of their combining with oxygen. Some have even believed that this gas is capable of reſtoring matters already putrid, or at leaſt which have begun to putrefy; but this I can ſcarcely believe.

226. It has been aſſerted alſo that this gas, extracted from carbonate of lime by ſulphuric acid, and uſed as an injection, is a good remedy for putrid diſeaſes; and that water impregnated with it diſſolves the ſtone in the bladder. It would be a matter of ſome importance to aſcertain whether theſe facts be true.

227. As the reſpiration of animals (215) and the combuſtion of bodies occaſion a continual conſumption of pure air, and cauſe carbonic acid gas to paſs into the atmoſphere in its ſtead, the fluid which we breathe, if not renewed, would ſoon become infectious and mortal. But the water with which the greater part of the ſurface of our globe is covered, abſorbs a large portion of this gas (217) and vegetation decompoſes another part; for the vegetable tiſſue abſorbs the carbon; and the oxygen which remains free, by combining with caloric, forms pure air (89); beſides, a part of the water which ſerves for vegetation is decompoſed; the hydrogen is abſorbed by the plant, and the oxygen remaining free, forms pure air (93).

228. As the four kinds of ſaline gas which follow are perfectly ſoluble in water, to obtain them with convenience, a mercurial pneumatic apparatus muſt be employed.

7. *Muriatic Acid Gas.*

229. The muriatic acid gas is nowhere to be found in a natural ſtate; it muſt therefore be produced by art: it is obtained by expoſing to heat fuming muriatic acid, put into a retort O M (*fig.* 11) the beak of which is introduced below a bell filled with mercury and placed on the ſhelf of a mercurial pneumatic apparatus. You may obtain it alſo with the ſame apparatus, if inſtead of muriatic acid you expoſe to heat a mixture of muriate of ſoda, or marine ſalt, and ſulphuric acid: the ſulphuric acid combines with the ſoda, the baſe of the marine ſalt; and the muriatic acid remaining free, paſſes into the ſtate of muriatic acid gas.

230. We have before ſaid (228) that muriatic acid gas is perfectly ſoluble in water, and in a very ſhort time. If you therefore introduce into the bell in which this gas has been collected, a ſmall quantity of water, the latter, by its relative lightneſs, will riſe to the ſurface of the mercury, the gas will immediately be entirely abſorbed and diſſolved in the water; the mercury will aſcend towards the top of the

bell, and the liquor found above the mercury will be real muriatic acid, more highly concentrated according as there is more gas and leſs water.

231. Muriatic acid gas therefore is nothing elſe than the muriatic acid itſelf deprived of water (73); that is to ſay, as much concentrated as poſſible, and combined with caloric, which makes it aſſume the gaſeous form.

232. Muriatic acid gas has a ſharp pungent odour. If a little of it be mixed with atmoſpheric air, it produces, like the muriatic acid, white fumes or vapours, occaſioned by the combination of the gas with the moiſture of the air, and which are more apparent, according as the air contains more moiſture.

233 The baſe, or radical, of the muriatic acid gas is ſtrongly combined with oxygen, for which it has ſo great an affinity, that it cannot be ſeparated from it. The nature of this radical is therefore unknown: its affinity for oxygen is ſo ſtrong, that it can even combine itſelf with a larger quantity of it than what is neceſſary to conſtitute it an acid; and it then forms oxygenated muriatic gas, of which we have already ſpoken (200 *et ſeq.*)

234. Muriatic acid gas is much heavier than atmoſpheric air: its ſpecific gravity is to that of air as 172·71 is to 100; and to that of diſtilled water

as

as 21·3482 is to 10000 : a cubic inch of this fluid weighs 0·7970 of a grain ; and the cubic foot 2ounces, 3 drams, 9·2160 grains *.

235. Muriatic acid gas gives the ſame ſigns of acidity as the muriatic acid itſelf ; and this indeed ought to be the caſe, as it is the ſame ſubſtance. It reddens blue vegetable colours ; but it deſtroys neither them nor any of the other colours, as the oxygenated muriatic gas does (204).

236. Muriatic acid gas combines with all the alkaline baſes, and forms with them muriatic ſalts. If it be mixed with ammoniacal gas, it combines with it, and forms a real muriate of ammonia.

237 It ſuffocates animals immerſed in it; and extinguiſhes a lighted taper ; but it firſt enlarges its flame, and makes it appear of a green or a bluiſh colour at the edges.

238. This gas is abſorbed by ſome porous bodies; as charcoal, ſponge, &c.

239. It diſſolves camphor ; it ſeizes on the ſuperabundant water of the ſulphate and borate of alumine, and reduces them to powder ; it cauſes ice to

---

* According to the new ſyſtem, a cubic decimetre of this gas weighs 2 grammes, 134 milligrammes ; and the cubic metre 2 chiliogrammes, 134 grammes, 83 milligrammes.

melt as ſpeedily as if it were thrown upon burning coals. In all theſe caſes it is abſorbed, and forms muriatic acid, ſimilar to that from which it was extracted.

240. All theſe phenomena are only the well-known effects of the great violence with which concentrated acids unite themſelves to water.

8. *Sulphurous Acid Gas.*

241 Sulphurous acid gas is nowhere found in a natural ſtate, and is entirely a production of art. It is obtained, in the ſame manner as the muriatic acid gas (229), by expoſing to heat in a retort O M, (*fig.* 12) ſulphuric acid, while it is exerciſing an action on ſome combuſtible body, ſuch as oil, charcoal, mercury, &c. ; in a word, on ſuch bodies as can take up a portion of the oxygen combined with the ſulphur contained in that acid ; for the ſulphurous acid is ſulphuric acid, deprived of a part of its oxygen. It is ſulphur combined with a leſs quantity of oxygen than that which is neceſſary to make it ſulphuric acid. The combuſtible body, therefore, takes a part of its oxygen from the ſulphuric acid, which by theſe means becomes ſulphurous acid ; and caloric combining with this ſulphurous acid, cauſes it to aſſume the gaſeous form. This proceſs requires a mercurial apparatus, becauſe ſulphurous acid gas is entirely ſoluble in water.

242. If

242. If you therefore put into the retort O M, already mentioned (241) ſulphuric acid over mercury, and expoſe it to heat, the mercury will be oxidated under the form of a white powder, and the ſulphuric acid, becoming ſulphurous acid, will paſs in the form of gas. When this operation is finiſhed, if you ſubſtitute another bell filled with mercury, and continue the heat, there will paſs another elaſtic fluid, which is pure air or oxygen gas, and the mercury will become liquid. The oxygen, which had before oxidated the mercury will eſcape by the heat, and form pure air by combining with caloric. In this experiment, therefore, a metal is, 1ſt, Oxidated; 2d, Revived; and the mercury is in no manner altered; it is found in the ſame ſtate as that in which it was when introduced into the retort. It is thence evident, that the two elaſtic fluids obtained are owing to the ſulphuric acid which is decompoſed.

243. Sulphurous acid gas is more than twice as heavy as atmoſpheric air. Its ſpecific gravity is to that of air as 205·43 is to 100, and to that of diſtilled water as 25·3929 is to 10000. A cubic inch of this gas weighs 0·9480 of a grain; and the cubic foot 2 ounces, 6 drams, 54·1440 grains *.

---

* A cubic decimetre of this gas weighs 2 grammes, 538 milligrammes; and the cubic metre, 2 chiliogrammes, 538 grammes, 407 milligrammes.

244. Sulphurous acid gas, like all the other ſuffocating gaſes, extinguiſhes burning bodies, and ſuffocates animals immerſed in it.

245. It deſtroys a great many of the vegetable colours; and in this reſpect approaches near to the oxygenated muriatic gas, of which we have already ſpoken (200 *et ſeq.)*

246. Sulphurous acid gas combines with alkalies, and forms with them neutral ſalts; but which differ from thoſe produced by the ſulphuric acid and the ſame alkalies, in their form, their ſavour, and particularly their property of being decompoſed by the weakeſt acids, and even the acetous acid.

247. This gas is not only ſoluble in water, as we have ſaid (241) but ſpeedily unites with it as often as it meets it, and it then becomes liquid ſulphurous acid: it therefore cauſes ice to melt as ſpeedily as the muriatic acid gas does (239).

9. *Fluoric Acid Gas.*

248. Fluoric acid gas is nowhere found in a natural ſtate; it cannot be procured without the aſſiſtance of art. It is obtained in the ſame manner as the preceding, by expoſing ſulphuric acid to heat in a retort O M (*fig.* 12) along with pulverized ſparry fluor, on which it exerciſes an action. The ſulphuric acid, by combining with the baſe of the ſparry fluor,

fluor, which is calcareous (251) diſengages from it another acid, that exiſted already formed in the ſpar; and this laſt acid combining with caloric, paſſes under the form of an elaſtic fluid, which is fluoric acid gas, known formerly under the name of *Sparry Acid Gas.*

249. For the firſt knowledge of this gas we are indebted to Margraff. The Duke de Liancourt, in a memoir publiſhed under the name of Boulanger, made us acquainted with ſome of its properties, and theſe were afterwards more fully illuſtrated by Scheele: but the nature of the fluoric radical is wholly unknown, becauſe it has never yet been poſſible to decompoſe this acid.

250. The gas muſt be collected over mercury, becauſe it is perfectly ſoluble in water, and even diſſolves ſpeedily in that fluid; but a ſolution of this gas in water is accompanied with a ſingular phenomenon, viz. the precipitation or depoſition of a very fine white earth, which is quartzy, or ſiliceous.

251. Fluoric acid gas, as Sceele ſuppoſed, is nothing elſe than a peculiar acid, extracted from ſparry fluor, the radical of which is unknown, and combined with caloric, that makes it aſſume the gaſeous form. This acid often holds in ſolution a vitrifiable earth, the quantity of which is greater when it is under the gaſeous than when it is under

the liquid form, becauſe when made to paſs from the ſtate of gas to that of a liquid, it depoſits a part of it. This earth does not ariſe from the ſpar, as ſuppoſed by Prieſtley, for the baſe of ſparry fluor is calcareous, as appears by the following proof. Fluoric acid gas precipitates lime diſſolved in water; and by combining with that lime, forms ſparry fluor. Whence then ariſes this vitrifiable earth? It is not improbable that it is furniſhed by the glaſs or earthen veſſels employed in extracting this gas; for that extracted in veſſels made of metallic ſubſtances, which Meyer employed, holds no earth in ſolution. It is at preſent well aſcertained that fluoric acid gas corrodes glaſs, and, in conſequence of this property, Puymorin conceived the idea of engraving on glaſs by means of this acid, in the ſame manner as is done on copper by the nitric acid.

252. Fluoric acid gas appears to be heavier than atmoſpheric air; but I have not yet been able to aſcertain exactly its ſpecific gravity.

253. This acid gives a ſtrong tint of red to blue vegetable colours: it extinguiſhes burning bodies, and ſuffocates animals immerſed in it.

254. Fluoric acid gas has a ſtrong penetrating ſmell, which approaches near to that of muriatic acid gas (232); but which, however, is a little more active. When mixed with common air, it forms, by combining

combining with its moiſture, white vapours as the muriatic acid gas does. Notwithſtanding this reſemblance to the muriatic acid, it is widely different; for, with alkalies, it forms fluoric neutral ſalts, exceedingly different from thoſe which are formed by muriatic acid gas with the ſame alkalies.

10. *Ammoniacal Gas.*

255. Ammoniacal gas is nowhere found in a natural ſtate; and muſt be produced by an artificial proceſs. To obtain it, put into a retort O M, (*fig.* 12) furniſhed with a bent tube, M N, a certain quantity of liquid ammonia, and heat the bottom of the retort with ſome kindled charcoal or a ſpirit of wine-lamp: having ſuffered the air to eſcape from the retort and the tube, you may collect the gas in bells filled with mercury, but not until the liquid has been brought to a ſtate of complete ebullition. To ſecure the bell from the introduction of water in ſteam, which would become condenſed in it and diſſolve the gas, it will be proper to place between the retort and the tube conveyed under the bell deſtined for collecting the gas, a ſmall veſſel which muſt be cooled with ice, in order to condenſe the water that might otherwiſe paſs in the form of vapour. By theſe means the ammoniacal gas may be obtained exceedingly dry and pure. In caſe ammonia ſhould not be at hand, you may ſupply its place by a mixture of three parts of quick-lime and one part of the

muriate

muriate of ammonia. This ſalt, which is compoſed of muriatic acid and ammonia, is then decompoſed; its acid combines with the lime, and the ammonia, which becomes free, combining with caloric, paſſes under the gaſeous form.

256. Ammoniacal gas could not be collected with a water-apparatus, and therefore it is neceſſary to employ mercury, becauſe this gas is perfectly ſoluble in water, and the ſolution forms liquid ammonia.

257. Ammoniacal gas, therefore, is nothing elſe than ammonia deprived of water (76) and in the moſt perfect ſtate of concentration, combined with caloric, which makes it aſſume the gaſeous form.

258. This ammoniacal gas, ſo pure, is itſelf compoſed of one part of hydrogen gas, of which we ſhall ſpeak hereafter (264 *et ſeq.*) and ſix parts of azotic gas, already mentioned (128 *et ſeq.*) combined together. This has been proved in the following manner by Berthollet:—If you mix together ammoniacal gas (255) and oxygenated muriatic gas (200) in a bell over mercury, the ammoniacal gas will be ſpeedily decompoſed: the exceſs of oxygen of the muriatic gas combines with the hydrogen the baſe of the hydrogen gas, one of the conſtituent parts of the ammoniacal gas, and forms water, while the oxygenated muriatic gas, by loſing its exceſs of oxygen, becomes ſimple muriatic acid,

and diſſolves in that water, and there remains an aeriform fluid which is azotic gas, another conſtituent part of ammoniacal gas. The whole is accompanied with heat, owing to the free ſtate of the caloric which was combined with the hydrogen gas and the oxygenated muriatic gas.

259. Ammoniacal gas is the lighteſt of all the ſaline gaſes, and is even much lighter than atmoſpheric air. Its ſpecific gravity is to that of air as 52·87 is to 100, and to that of diſtilled water as 6·5357 is to 10000. A cubic inch of this gas weighs 0·2440 of a grain; and the cubic foot 5 drams 61·6320 grains [*].

260. Ammoniacal gas has a penetrating odour, and an acid cauſtic taſte. It ſpeedily gives a ſtrong tint of green to blue vegetable colours.

261. It combines rapidly with the carbonic, muriatic, and ſulphurous acid gaſes, and immediately forms neutral ſalts, exciting a great deal of heat, which ariſes from the free ſtate of the caloric that had been combined with theſe gaſes. All theſe ſalts are ammoniacal.

262. Ammoniacal gas ſuffocates animals and extinguiſhes burning bodies, like all the other ſuffocating gaſes; but as it is ſlightly inflammable on account

---

[*] A cubic decimetre of this gas weighs 653⅓ milligrammes; and the cubic metre 653 grammes 345 milligrammes.

of the hydrogen gas that enters into its compoſition (258) it increaſes the flame of a taper, and makes it become larger before it extinguiſhes it.

263. Ammoniacal gas, when brought into contact with water, is ſpeedily abſorbed and diſſolved by it, and it then forms ammonia ſimilar to that from which it has been extracted (255). If the water is in the ſtate of ice, the ammoniacal gas cauſes it immediately to melt and produces great cold, becauſe it is neceſſary that a large quantity of caloric ſhould be combined with ice to make it melt (332). On the other hand, the ammoniacal gas produces heat when it diſſolves in water already fluid, becauſe the water having no need of a new quantity of caloric, that of the gas aſſumes a free ſtate.

ORDER III.

Inflammable, or Hydrogen Gaſes.

264. The hydrogenous gaſes, known under the name of *Inflammable Gaſes* (62) are found in a natural ſtate in the ſlime of muddy waters, and in marſhes, in metallic mines, in coal-pits, and in the bowels of animals. They are exhaled from privies, burying-grounds, and, in a word, from all places where there are animal or vegetable matters in a ſtate of putrefaction; and they thence riſe into the

atmoſphere. But in all theſe caſes they are never very pure.

265. Hydrogen gas may be obtained in a ſtate of purity by the aſſiſtance of art; that is, by decompoſing water, ſince its baſe is one of the conſtituent parts of water (78); this baſe, therefore, has been called *Hydrogen*, that is, the generator of water. With its baſe we are as yet unacquainted. We are ignorant of the nature of this ſubſtance, becauſe it cannot be ſeparated from the caloric which gives it the gaſeous form, without fixing it in another body.

266. Till lately, water was conſidered as a ſimple ſubſtance or element; no one had ever been able to decompoſe it; at leaſt, the decompoſition of it which is now daily effected, had eſcaped obſervation. We ſhall, however, give ſuch evident proofs of the decompoſition and recompoſition of water, as will clearly ſhew that it is not a ſimple ſubſtance; that is, not an element.

Decompoſition of Water.

267. *Exp.*—A tube of common glaſs E F (*fig.* 13) well annealed, and difficult to be fuſed, about

ten or eleven lines in diameter *, was placed acroſs a furnace C F E D, in a poſition ſomewhat inclined, and to its upper extremity was adapted a glaſs retort A, containing a known quantity of diſtilled water, and reſting on a furnace V V. To the lower extremity of the glaſs tube F, was applied a worm S S, connected with the double tubulated flaſk H; and to the other tubulure was adapted a bent glaſs tube K K, deſtined to convey the gas to an apparatus proper for determining the quality and quantity of it. When the whole was thus arranged, a fire was kindled in the furnace C F E D, and maintained in ſuch a manner as to bring the glaſs tube E F to a red heat, but without fuſing it: at the ſame time as much fire was maintained in the furnace V V X X as to keep the water in the retort A in a continual ſtate of ebullition.

268. *Effect.* — In proportion as the water in the retort A aſſumed the ſtate of vapour by ebullition, it filled the interior part of the tube E F, and expelled the atmoſpheric air which was evacuated by the worm S S and the tube K K. The ſteam of the water was afterwards condenſed by cooling in the worm S S, and fell, drop by drop, in the ſtate of water, into the tubulated flaſk H. When the whole of the water in the retort A was evaporated,

---

* In making this experiment, it will be proper to cover the tube with a luting of clay mixed with pounded earthen ware and to ſupport it in the middle, that it may not bend.

rated, and the liquor in the veſſels had been ſuffered to drain off completely, there was found in the flaſk H a quantity of water exactly equal to that which was in the retort A; and there had been no diſengagement of any gas; ſo that this operation was merely a common diſtillation, which gave abſolutely the ſame reſult as if the water had never been brought to a ſtate of incandeſcence in paſſing through the glaſs tube E F.

269. *Exp.*—Every thing being arranged as in the preceding experiment, 28 grains of charcoal reduced to fragments of a moderate ſize, and which had been previouſly expoſed for a long time to a white heat in cloſe veſſels, were introduced into the glaſs tube E F. The operation was then conducted as before, and the water in the retort A kept in a continual ſtate of ebullition till it was totally evaporated.

270. *Effect.*—The water in the retort A was diſtilled, as in the preceding experiment; and being condenſed in the worm S S, had fallen, drop by drop, into the flaſk H; but at the ſame time there had been diſengaged a conſiderable quantity of gas which eſcaped through the tube K K, and was collected in a proper apparatus. When the operation was finiſhed, there was found nothing in the tube E F but a few aſhes; and the 28 grains of charcoal had totally diſappeared.

271. The gaſes diſengaged were found to weigh altogether, - - grs. 113·7

There were found two different kinds of gas, viz. 144 cubic inches of carbonic acid gas (211) weighing - 100

And 380 cubic inches of a very light gas, weighing - - 13·7

This laſt gas took fire on being applied to a lighted body in contact with the air.

In examining afterwards the weight of the water which had paſſed into the flaſk, it was found leſs than that in the retort, A by - - - 85·7

In this experiment, therefore, 85·7 grains of water and 28 grains of charcoal, formed carbonic acid gas equal to - 100

And a peculiar gas ſuſceptible of inflammation, equal to - - 13·7

272. We have already ſaid (211) that to form 100 grains of carbonic acid gas, 72 grains of oxygen muſt be united to 28 grains of charcoal or carbon. The 28 grains of charcoal put into the glaſs tube EF took therefore from the water 72 grains

grains of oxygen, ſince there was formed carbonic acid equal to - grs. 100

It appears, therefore, that 85·7 grains of water are compoſed of 72 grains of oxygen, and 13·7 grains of a ſubſtance forming the baſe of a gas ſuſceptible of inflammation. The following is a proof of it:

273. *Exp.* The apparatus being arranged, as above, inſtead of the 28 grains of charcoal, 274 grains of thin ſhavings of iron, rolled up in a ſpiral form, were introduced into the tube E F: the tube was then brought to a red heat as before; and in the like manner the whole of the water in the retort A was made to evaporate.

274. In this experiment there was diſengaged only one kind of gas which was inflammable: there was obtained of it about 406 cubic inches, weighing - grs. 15

The 274 grains of iron, put into the tube EF, were found to weigh above what they did when introduced - - 85

And the water firſt employed was diminiſhed 100

The volume of theſe iron ſhavings was found to be greatly enlarged. The iron was ſcarcely any longer ſuſceptible of attraction by the magnet; it diſſolved without efferveſcence in acids: in a word, it was in

the

the ſtate of a black oxide, like that which has been burnt in oxygen gas.

275. In this experiment there was a real oxidation of the iron by the water, entirely ſimilar to that effected in the air by the aid of heat; 100 grains of water were decompoſed; and of theſe 100 grains 85 united to the iron, to reduce it to the ſtate of black oxide: theſe 85 grains, therefore, were oxygen; the remaining 15 grains, combined with caloric, formed an inflammable gas. It thence follows that water is compoſed of oxygen and the baſe of inflammable gas, in the proportion of 85 to 15, or of 17 to 3.

276. Water therefore, beſides oxygen, which is one of its principles, and which is common to it, with a great many other ſubſtances, contains another peculiar to itſelf, and which is its conſtituent radical. This radical has been called *Hydrogen*; that is to ſay, *the generator of water*; and the combination of this radical with caloric, is diſtinguiſhed by the name of *Hydrogen Gas*.

277. This radical then is a new combuſtible body; that is to ſay, a body which has ſo much affinity for oxygen as to be able to take it from caloric, and to decompoſe vital air, or oxygen gas. This combuſtible body itſelf has ſo great an affinity for caloric, that unleſs engaged in ſome combination, it is always in

the aeriform, or gaſeous ſtate, at the degree of preſſure and temperature in which we live.

Recompoſition of Water.

278. If it be true, as we have proved, that water is compoſed of hydrogen, combined with oxygen, it thence reſults, that by re-uniting theſe principles, water ought to be re-formed. This indeed is what takes place, as will be ſeen, by the following experiment.

279. *Exp.* Take a wide-mouthed glaſs balloon A (*fig.* 14) capable of containing about 30 pints, and cement to its mouth a ſmall plate of copper BC, having above it a cylinder of the ſame metal, *g*D, pierced with three holes to receive three tubes. The firſt of theſe, *h*H, is deſtined to be connected at its extremity *h*, with an air-pump, in order that the balloon A may be exhauſted of air. The ſecond tube, *gg*, communicates by its extremity MM, with a reſervoir of oxygen gas, and is deſtined to convey it into the balloon A. The third tube, *d*'D*d*, communicates by the extremity NN, with a reſervoir of hydrogen gas: the extremity of this tube terminates in an aperture ſo ſmall as ſcarcely to admit a very delicate needle. It is through this aperture that the hydrogen gas contained in the reſervoir is to paſs into the balloon A. In the next place, the ſmall plate B C, is pierced with a fourth hole, into which

is inſerted with cement, a glaſs tube, through which paſſes a wire FL, having at its extremity L, a ſmall ball deſtined to make an electric ſpark paſs between the ball and the extremity *d'*, of the tube that conveys the hydrogen gas into the balloon A. The wire FL is moveable in the glaſs tube, in order that the metallic ball L may be brought nearer to or removed from the point *d'* : the other three tubes *h* H, *gg*, *d'*D *d*, are each furniſhed with a cock.

280. That the gaſes may be conveyed in a very dry ſtate through the tubes which conduct them into the balloon A, and that they may be deprived of water as much as poſſible, you muſt put into the ſwelled parts M M and N N of the tubes, ſome ſalt capable of attracting the moiſture with great activity, ſuch as acetite of potaſh, muriate of lime, or nitrate of lime. Theſe ſalts ſhould be only coarſely pounded, in order that they may not form a maſs, and that the gaſes may paſs freely into the interſtices left between the fragments. You muſt be provided with a ſufficient quantity of very pure oxygen gas, and nearly a triple volume of hydrogen gas, equally pure. To obtain it in this ſtate, and free from all mixture, you muſt extract it from water, decompoſed by means of very pure and ductile iron.

281. When every thing has been thus prepared, adapt to the air-pump the tube *h* H, and exhauſt the air in the large balloon A ; then fill it with oxygen gas, by means of the tube *gg*, and by a certain

degree of preſſure, force the hydrogen gas to paſs into the balloon A, through the extremity *d'* of the tube *d*D*d'*; then kindle this gas by means of an electric ſpark, and if you renew the quantity of each of theſe two gaſes, the combuſtion may be continued for a long time.

282. *Effects.* In proportion as the combuſtion proceeds, water is depoſited on the internal ſurface of the balloon A: the quantity of this water gradually increaſes, and it unites itſelf into large drops, which run down the ſides of the veſſel, and are collected in the bottom of it.

283. Lavoiſier, who performed this experiment in the preſence of a commiſſion appointed by the Academy of Sciences, had taken proper means to aſcertain the weight of the gaſes employed. Before the experiment, he weighed the balloon A; and by weighing it after the operation, he was enabled to obtain the weight of the water that had been formed. In this experiment, therefore, he had a double proof: On the one hand, the weight of each of the gaſes employed; and, on the other, the weight of the water formed; and theſe two quantities were found to be equal, within a two-hundredth part. It was by an experiment of the ſame kind that Lavoiſier aſcertained that 85 parts, by weight, of oxygen, and 15 parts alſo by weight, of hydrogen, are required to compoſe an hundred parts of water.

284. To form a cubic metre of water, weighing 1000 chiliogrammes, will require therefore 850 chiliogrammes of oxygen gas, and 150 chiliogrammes of hydrogen gas. The volume of oxygen gas neceſſary for this purpoſe will be equal to 634 cubic metres, 886 cubic decimetres, 354 cubic centimetres, and 187 cubic millimetres, *plus* 32 thouſandth parts of a cubic millimetre. This volume of oxygen gas will weigh 850 chiliogrammes, or 1736 pounds, 7 ounces, 0 drams, and 69·5 grains *poids de marc.*— The volume of the hydrogen gas required, will be equal to 1514 cubic metres, 37 cubic decimetres, 404 cubic centimetres, and 127 cubic millimetres, *plus* 276 thouſandth parts of a cubic millimetre. This volume of hydrogen gas will weigh 150 chiliogrammes, or 306 pounds, 6 ounces, 7 drams, and 16·5 grains, *poids de marc.* If theſe two volumes of gas be burnt together, the reſult will be a cubic metre of water, weighing 1000 chiliogrammes, or 2042 pounds, 14 ounces, 0 drams, 14 grains, *poids de marc.*

285. It is therefore clearly proved that water is not a ſimple ſubſtance; that it is compoſed of two principles, *oxygen* and *hydrogen*; and that its two principles ſeparated from each other, have ſo great an affinity for caloric, that at the common degree of temperature and preſſure they cannot exiſt but under the gaſeous form.

286. Theſe phenomena of the decompoſition and recompoſition of water, are continually effected before our eyes, by the temperature of the atmoſphere and the agency of compound affinities. It is this decompoſition which gives riſe, at leaſt in a certain degree, to the phenomena of ſpirituous fermentation, thoſe of putrefaction, and thoſe even of vegetation.

287. You will obtain *hydrogen gas*, therefore, from water, as often as you bring into contact with the latter any body expoſed to heat and the action of an acid, and which has a greater affinity for oxygen than oxygen has for hydrogen. Iron and zinc, as well as charcoal and oils, are of this kind, and conſequently are capable of decompoſing water, by ſeizing on its oxygen. If an acid be employed, you muſt take care to dilute it with water, becauſe it is the water which furniſhes the hydrogen; without it, you will obtain no gas.

288. You may obtain *hydrogen gas* alſo by means of combuſtible, animal, and vegetable ſubſtances, analyzed with an open fire. It is always the water of theſe ſubſtances which, in conſequence of its being decompoſed, furniſhes the greateſt quantity; for its oxygen combines with theſe ſubſtances, and its hydrogen combining with caloric, paſſes under the form of gas.

289. Hydrogen gas, therefore, is only of one kind, in whatever place it may have been found, or

whatever may have been the matters employed to extract it; but it may be mixed with different ſubſtances, or hold ſome of them in ſolution; and this is what forms its varieties, which are in number five, viz. *Sulphurated hydrogen gas*, *phoſphorized hydrogen gas*, *carbonated hydrogen gas*, *carbonic hydrogen gas*, *and hydrogen gas of the marſhes.*

We ſhall firſt ſpeak of *pure hydrogen gas*, free from any mixture, and then proceed to examine its varieties.

11. *Pure Hydrogen Gas.*

290. Pure hydrogen gas has a ſtrong and diſagreeable odour.

291. It exhibits no ſigns of acidity. It neither precipitates lime diſſolved in water, nor reddens tincture of turnſole; for if you pour lime-water or tincture of turnſole into a veſſel filled with this gas, the colour of the tincture is not changed, nor is the lime precipitated.

292. When *hydrogen gas* is perfectly pure, it may be preſerved without alteration, in bottles cloſely ſtopped: it would keep equally well if there were water in them, becauſe it is totally inſoluble in that liquid.

293. Pure hydrogen gas is the lighteſt of all the elaſtic fluids. Its ſpecific gravity is to that of air, as 8·02 is to 100; and to that of diſtilled water, as 0·9911 is to 10000. A cubic inch of this gas weighs 37 thouſandths of a grain; and the cubic foot 63·936 grains.*

294. Hydrogen gas ſuffocates animals like all the other ſuffocating gaſes; but by occaſioning violent convulſions.

295. Though this gas is one of thoſe ſubſtances which readily inflame, it extinguiſhes burning bodies; ſuch, for example, as a taper when immerſed in it: the taper, on entering the gas, makes it inflame at the ſurface; but the taper becomes extinguiſhed when completely immerſed; for the gas inflames only at the place where it is in contact with the air. If its points of contact with the air, however, be multiplied, as is the caſe when it is mixed with air, it then inflames altogether, and explodes like gunpowder. This exploſion will be more violent the nearer the air approaches to its ſtate of purity.

296. Hydrogen gas is capable of decompoſing ſulphuric acid, and of reducing it to the ſtate of ſulphurous acid, by depriving it of a part of its oxygen; for

---

* According to the new French ſyſtem of weights and meaſures, a cubic decimetre of this gas weighs 99·073 milligrammes (1·865 grains); and the cubic metre 99 grammes, 73 milligrammes (1865½ grains).

for which its baſe or hydrogen has more affinity than ſulphur has; and this combination of oxygen and hydrogen forms water, while the ſulphurous acid aſſumes the gaſeous form.

297. We have already ſaid (264) that hydrogen gas is exhaled from mines, miry water, marſhes, common ſewers, burying-grounds, &c. it may therefore be readily conceived, that it is the cauſe of thoſe luminous phenomena, *Will. with the wiſp*, &c. often ſeen above ſuch places. Its lightneſs (293) allows it to riſe to a conſiderable height in the atmoſphere; and as it can be ſet on fire by an electric ſpark, it is probable that it often inflames during ſtorms, and that it increaſes the detonation of thunder. This is no doubt the reaſon why thunder is more frequent and ſtronger in ſome places than in others. When this gas burns in ſuch caſes, its baſe or hydrogen combining with the oxygen of the air, forms water, which falls down in rain. During ſtorms, indeed, violent and ſudden rains take place after ſome claps of thunder.

298. Hydrogen gas has become a fluid highly intereſting to philoſophers, and particularly to aeronautes, ſince it is employed for filling air-balloons.—Its ſpecific lightneſs (293) is the cauſe of the aſcenſion of theſe machines.

299. Attempts have been made alſo to render it a ſubſtitute for combuſtible matters, in chaffing-diſhes

and

and lamps. Neret, in the *Journal de Phyſique* for January 1777, has given a deſcription of a hydrogen gas chaffing-diſh. Furſtenberger, a philoſopher of Bâle; Brander, a mechanic of Augſbourg; and Ehrman, lecturer on philoſophy at Straſburgh, have invented hydrogen gas lamps, which can be lighted in the night-time by means of an electric ſpark. But it is neceſſary that great precaution ſhould be uſed, to prevent the introduction of atmoſpheric air into the lamp, which would occaſion a violent detonation (295), and cauſe the veſſel to burſt, to the great danger of any perſon near it.

300. It is now certain that hydrogen gas is a ſubſtance of a determinate nature, always the ſame, and into the compoſition of which there enters a great deal of caloric very little confined, and almoſt in the ſtate of free fire. But this kind of gas may be mixed with other ſubſtances, and hold ſome of them in ſolution. This is what forms its varieties, of which we are about to treat.

12. *Sulphurated Hydrogen Gas.*

301. Sulphurated hydrogen gas is that which holds ſulphur in ſolution, and which is known under the name of *Hepatic Gas* (79). Gengembre, who analyſed it, conſiders it as being formed of pure hydrogen gas and ſulphur very much divided. It is

this ſulphur which it holds in ſolution, that gives it its diſtinguiſhing characters.

302. Sulphurated hydrogen gas may be obtained from the ſolid ſulphurets, when decompoſed by acids diluted with water in a pneumato-chemical apparatus (65). The ſulphuret ſeizes on the oxygen of the water; and its hydrogen, by combining with a part of the ſulphur and the caloric, forms this gas.

303. I am unacquainted with its ſpecific gravity, but it is certainly much heavier than pure hydrogen gas (893); it is ſoluble in water. It is the ſulphur, no doubt, which makes it ſoluble, and renders it ſo heavy.

304. Sulphurated hydrogen gas has an exceedingly fetid odour, and, like the other varieties, poſſeſſes the property of ſuffocating animals. It renders ſyrop of violets green.

305. Pure air, when mixed with this gas, decompoſes it, in conſequence of the combination of its oxygen with the hydrogen of the gas; and by theſe means precipitates from it the ſulphur. For the ſame reaſon, this gas is decompoſed alſo, and its ſulphur precipitated by the nitrous acid, the ſulphurous acid, and, in certain circumſtances, by the oxygenated muriatic acid. In all theſe caſes water is formed.

306. Sulphurated hydrogen gas inflames, when brought into contact with a burning body, and even by an electric ſpark. It emits a reddiſh blue flame; and during its combuſtion depoſits ſulphur on the ſides of the veſſels that contain it. The degree of heat which inflames the gas is too weak to burn the ſulphur.

307. It is ſulphurated hydrogen gas that forms the ſulphurous or hepatic mineral waters; ſuch as thoſe of Enghien, Bonnes, Baredge, Cautereſtz, &c.

13. *Phoſphorized Hydrogen Gas.*

308. Phoſphorized hydrogen gas is that which holds phoſphorus in ſolution (80). It was diſcovered by Gengembre, who obtained it by boiling a ley of potaſh with half its weight of phoſphorus, cut into ſmall morſels, and receiving the aeriform fluid, diſengaged from it, in bells filled with mercury. It could not be collected over water, becauſe it is exceedingly ſoluble in that fluid. It is the phoſphorus, no doubt, that renders it ſo ſoluble in water.

309. Phoſphorized hydrogen gas has a very fetid odour: like the reſt, it poſſeſſes the property of ſuffocating animals.

310 It inflames merely by the contact of the air, and produces an exploſion which would be exceedingly

ingly ſtrong, and even dangerous, if too large a portion of it were preſented to the air at once: only a ſmall quantity of it muſt be uſed for performing this experiment: a bubble of only the ſize of a cheſnut will be ſufficient. The phoſphorus which this gas holds in ſolution, takes fire on being brought into contact with the air, and communicates to the gas its inflammation. While this gas burns, it emits fumes which, when the air is calm, form a kind of circular crown, that increaſes in diameter as it riſes. Theſe fumes are concrete phoſphoric acid.

311. If you introduce pure air into a bell, partly filled with phoſphorized hydrogen gas, and placed over a mercurial pneumatic apparatus (65), the gas will inflame with a wonderful ſplendor: it burns with great rapidity, producing a thick white ſmoke; and it excites ſo ſtrong a heat, and occaſions ſo great rarefaction, that the bell will burſt, unleſs made of very thick glaſs.

14 *Carbonated Hydrogen Gas.*

312. Carbonated hydrogen gas is that which holds carbon in ſolution (81). It is now well known that charcoal, though exceedingly fixed in cloſe veſſels, and over a common fire, contains a carbonaceous principle, which has obtained the name of *Carbon*, ſuſceptible of being reduced into vapour by a very ſtrong heat, and of being diſſolved in aeriform

form fluids. Hydrogen gas, in particular, poſſeſſes the property of diſſolving this carbonaceous principle: it often, therefore, when it aſſumes the gaſeous form, carries ſome of this ſubſtance along with it.

313. Hydrogen gas, thus *carbonated*, may be obtained if you make ſulphuric acid, diluted with water (273) to exerciſe its action, not on ſoft iron, but on caſt iron or ſteel, becauſe both theſe contain this carbonaceous principle. Caſt iron abſorbs it in the ſmelting-furnaces, as ſteel does during the proceſs of cementation: which clearly proves, contrary to the opinion of the old chemiſts, that ſteel is iron, not ſo pure as that of which it was formed.

314. Carbonated hydrogen gas is much heavier than pure hydrogen gas; and, conſequently, is not that kind which ought to be employed for filling air-balloons: it would be too heavy, and would require a balloon of too great ſize. Great care, therefore, ought to be taken that there be no ſteel mixed with the filings of iron, generally uſed for extracting the gas deſtined to fill theſe machines.

315. Carbonated hydrogen gas burns with a blue flame; and, during combuſtion, throws out ſmall white or reddiſh ſparks.

316. Carbon may be immediately diſſolved in hydrogen gas. If you cauſe a piece of charcoal to float

float over mercury, in a bell of glaſs, and throw the concentrated rays of the ſun upon it by means of a burning glaſs, you will, by this proceſs, obtain carbonated hydrogen gas.

15. *Carbonic Hydrogen Gas.*

317. Carbonic hydrogen gas is that which is merely mixed with carbonic acid gas (211); but without any combination (82).

318. It may be obtained by the diſtillation of various vegetable matters; but, in particular, of the acidulous tartrite of potaſh, and of all the tartareous and acetous ſalts, the hard kinds of wood, pit-coal and charcoal moiſtened with water before being burnt, &c.

319. Carbonic hydrogen gas burns with difficulty; yet if only one part of pure hydrogen gas be mixed with three parts of carbonic acid gas, the latter will not prevent the mixture from being inflammable.

320. Hydrogen gas may be ſeparated from the carbonic acid mixed with it, by means of lime-water and alkalies, with which the carbonic acid combines.

321. Carbonic hydrogen gas may be made artificially, by mixing pure hydrogen gas with carbonic acid gas, in whatever proportion you chooſe; which proves that this gas is neither of a peculiar kind, nor even a variety of hydrogen gas: it is merely a mixture of the two gaſes.

16. *The Hydrogen Gas of Marſhes.*

322. The hydrogen gas of marſhes, called, by Volta, *Inflammable Air*, or *Gas of the Marſhes*, is that which is merely mixed with mephitic or azotic gas (83).

323. It diſengages itſelf from the miry water of marſhes, from quagmires, ponds, common ſewers, and privies, and from all places where animal matters putrefy in water. It is produced, therefore, by the putrefaction of ſome vegetable matters, and by all animal ſubſtances.

324. It is nothing but a mere mixture, without any combination, of pure hydrogen gas (290) and azotic gas (128); for a combination of theſe two fluids would produce ammoniacal gas (258), which would be ſoluble in water; and the hydrogen gas of marſhes is not. For an accurate knowledge of this gas we are indebted to Berthollet.

325. The hydrogen gas of marſhes burns with a blue flame : mixed with pure air it detonates only with difficulty. When made to detonate in Volta's eudiometer, there were found drops of water and a reſiduum of azotic gas, more or leſs pure. The water is produced by the combination of the hydrogen gas with the oxygen of the air ; and the mofetta, or azote, remains under the gaſeous form.

326. That the reader may be enabled at one view to compare the ſpecific gravities of the elaſtic fluids, I have here ſubjoined all thoſe that are known.

327. *Specific Gravities of the Elaſtic Fluids compared with that of Air.*

Atmoſpheric air,	100·00
Pure oxygen gas,	108·35
Azotic gas,	96·31
Nitrous gas,	105·35
Carbonic acid gas,	150·60
Muriatic acid gas,	172·71
Sulphurous acid gas,	205·43
Ammoniacal gas,	52·87
Pure hydrogen gas,	8·02

328. *Specific Gravities of the Elaſtic Fluids compared with that of Water.*

Diſtilled water,	10000·0000
Atmoſpheric air,	12 3609

Pure

Pure air, or oxygen gas,	13·3929
Azotic gas,	11·9048
Nitrous gas,	13·0179
Carbonic acid gas,	18·6161
Muriatic acid gas,	21·3482
Sulphurous acid gas,	25·3929
Ammoniacal gas,	6·5357
Pure hydrogen gas,	0·9911

Of the Phyſical Properties of Water.

329. With the nature of water we are now well acquainted. We have proved (266 *et ſeq.*) that it is compoſed of 17 parts in weight of the baſe of pure air, called *Oxygen*, and three parts of the baſe of hydrogen gas, called *Hydrogen* (275). The queſtion now is to examine its phyſical properties. To know them is of the more importance, as this fluid is as neceſſary to us as air; and though we have not occaſion for it every moment, as we have for air, it would be impoſſible for us to continue long in exiſtence without it. Water, or its conſtituent parts, enter into a great number of the productions of nature; without it there would be no vegetation: it is the beverage of men and animals; and it is highly eſſential, in other reſpects, to the convenience and comforts of life.

330. Water preſents itſelf to us in three different ſtates; 1ſt, In the ſtate of *ice*—a ſtate in which it is not combined with caloric; 2d, In that of a *liquid*,

in which it is combined with a certain quantity of caloric; 3d, In that of *vapour*, in which it is penetrated by a very large quantity of caloric, either combined with it or free. Theſe three modes of exiſtence, which do not in any manner change its eſſence, render it proper for producing different effects. As the liquid ſtate is that in which it generally preſents itſelf, we ſhall firſt examine it as a *liquid*, then as *vapour*, and, in the laſt place, as *ice*.

Water conſidered in the State of Liquid.

331. Water in the liquid ſtate is an inſipid fluid; viſible, tranſparent, colourleſs, inodorous, almoſt incompreſſible, very little elaſtic; it adheres to the ſurface of moſt bodies; diſſolves a great number of them, and penetrates more; and is capable of extinguiſhing inflammable matters immerſed in it, or on which it is thrown in a ſufficient quantity. This definition is not applicable in its full extent, but to water perfectly pure; and, therefore, if it be opake, coloured, odorous, or have any taſte, it is certainly mixed with ſome foreign matter.

332. The liquidity of water ariſes from its being combined with a quantity of caloric, equal to three-fourths of that neceſſary for bringing it to ebullition; it is this combined caloric that maintains the mobility of its parts, in which its liquidity conſiſts: as ſoon as this combination is deſtroyed, its parts approach

proach each other, and adhere to ſuch a degree, as to form a ſolid body known under the name of *Ice* (348). All other ſubſtances ſuſceptible of becoming liquid, aſſume that form, in conſequence of the ſame cauſe.

333. We are furniſhed with water two ways: 1ſt, From the atmoſphere by rain, ſnow, hail, &c. (171); 2d, From the boſom of the earth by ſprings and fountains, which afterwards form rivulets and rivers, that diſcharge their waters into the ſea.

334. Of all the natural kinds of water, the pureſt is that of rain: if it happens to be mixed with foreign matters, they are volatile, and eaſily diſengage themſelves from it. Every other kind almoſt always holds in ſolution ſome foreign ſubſtances that give it qualities which it does not naturally poſſeſs. Theſe ſubſtances are often ſaline, or metallic; and they then form what are called *mineral waters.*

335. When water contains too great a mixture of foreign ſubſtances, means muſt be deviſed for purifying it. The moſt uſual proceſs employed for this purpoſe is filtration; but the moſt effectual is diſtillation. Filtration purifies water only from the coarſer matters which it contains, and every thing diſſolved in it paſſes with the liquid through the filter; whereas diſtillation purifies it from every thing fixed in it; and the volatile ſubſtances which paſs over with it are again ſpeedily volatilized, and

leave it perfectly pure. Diſtillation, therefore, is the only efficacious method of rendering ſea-water potable.

336. Water, as well as other liquors, does not appear to be compreſſible; that is to ſay, whatever be the force employed, it is not poſſible to make its volume ſenſibly decreaſe. It muſt not, however, be conſidered as abſolutely incompreſſible; for it is elaſtic, ſince it tranſmits ſound; and every elaſtic body is neceſſarily compreſſible.

337. The particles of water have a certain adheſion to each other. A proof of this is, that a drop of water remains ſuſpended at the tip of the finger, though the lower particles of the drop adhere only to other particles of water.

338. If water, at the moment when it ceaſes to be ice, be expoſed over the fire in an open veſſel, and ſubjected to the preſſure of the atmoſphere, it becomes hot, and expands until it boils, and not afterwards, however long it may be heated: when rarefied as much as it can be, its volume is increaſed $\frac{1}{26}$, and it has then 212 degrees of heat.

339. Water introduces itſelf into and penetrates a great number of different kinds of bodies, and even ſome of the hardeſt; for it penetrates freeſtone, and all ſtones that do not ſtrike fire with ſteel, except gypſum, barytes, ſpar, alabaſter, and marble.

340. Water is the ſolvent of many bodies; but the ſubſtances which diſſolve in it ſooneſt, or in the greateſt quantity, are ſalts. It does not diſſolve the ſame quantity of all the kinds of theſe bodies; ſome of them are more ſoluble than others; and of each kind, the water diſſolves a greater quantity according as it is hotter.

341. The ſolution of ſalts in water exhibits the following ſingular phenomenon: A ſalt, by diſſolving in water, *generally* cools it; I ſay generally, becauſe we muſt except ſome of them; ſuch as the carbonate of potaſh, acetite of lead, and the ſulphates of magneſia, iron, copper, and zinc. The ſalt moſt proper for cooling water, by diſſolving in it, is the muriate of ammonia; and for this reaſon, no doubt, that being very ſoluble, it renders the operation ſpeedier; and by theſe means, makes the cooling more ſenſible. It may, therefore, be ſubſtituted with advantage in the room of ice, for cooling liquors.

342. Water is capable of extinguiſhing burning bodies, provided it can exiſt on them in the liquid ſtate longer than the combuſtion can laſt; for in that caſe it prevents the contact of the air: a fluid abſolutely neceſſary for the combuſtion of bodies (100, 161). But if it becomes vaporized and is decompoſed, its oxygen combines with the burning body; and its hydrogen (285) by combining with

caloric,

caloric, forms inflammable gas; which inflaming, tends greatly to increaſe the violence of the fire.

Water conſidered in the State of Vapour.

343. If water be warmer than the ſurrounding air, the caloric, which always tends to diffuſe itſelf in an uniform manner when it iſſues from the water, carries with it the moſt ſubtile parts and thoſe which have the leaſt adheſion to the whole maſs, and combining with them, reduces that portion of the water to the ſtate of vapour, or of elaſtic fluid. This fluid has peculiar properties which diſtinguiſh it from water in the liquid ſtate.

344. Vapour when it paſſes into dry air, the temperature of which is pretty high (as, for example, from 72 to 77 degrees) is perfectly inviſible.

345. But if the air which receives the vapour is already charged with water, and if its temperature be only from 47 to 50 degrees, the vapour then becomes apparent, and forms in it a very ſenſible cloud of a greyiſh white colour. For this reaſon, water taken from a pretty deep well in winter is often ſeen to ſmoke; but this is never the caſe in ſummer.

346. The combination of caloric with the aqueous parts, rarefies them to ſuch a degree, that in this ſtate of elaſtic fluid, they occupy a volume 12 or

1400 times greater than that which they occupied in the liquid ſtate, which gives them a ſpecific lightneſs, ſufficient to raiſe them in the atmoſphere. But if the vapour is expoſed to a great degree of heat, it aſſumes a volume ſtill larger. The heat of boiling water, which rarefies water only $\frac{1}{16}$, (338) rarefies vapour to ſuch a degree, as to make it occupy a volume 13 or 14000 times greater than that of the water which formed it.

347. If vapour be retained by any obſtacles, the heat increaſes its expanſive force as much as it would have increaſed its volume if it had been at full liberty to expand. In conſequence of this augmentation of its expanſive force, it makes prodigious efforts againſt every thing that reſiſts it, and is then capable of overcoming conſiderable obſtacles. We have a very ſtriking inſtance of this property in thoſe noble machines called *Steam-Engines.*

Water conſidered in the State of Ice.

348. We have already ſaid (332) that water is never in the liquid ſtate, except when combined with a quantity of caloric ſufficient to maintain its parts moveable among themſelves. When in the neighbourhood of cold air, it loſes its free caloric and becomes cool, but it remains liquid; if it then loſes its combined caloric, its parts approach nearer, touch each other more intimately, and by the force

of coheſion, adhere in ſuch a manner as to form a hard body called *Ice*. This tranſition of water from the ſtate of liquid to that of ice, is owing therefore only to the want of combined caloric.

349. Water when it approaches to congelation, increaſes its volume, as experience ſhews. The ſpecific gravity of ice, therefore, is leſs than that of water; which is clearly proved by its floating on it.

350. The ice of running water is formed in a manner quite different from that of ſtagnant water. When cold exerciſes an action on water in a ſtate of reſt, it firſt cauſes the ſurface to freeze: being then communicated from ſtratum to ſtratum, and penetrating the whole thickneſs of the water, it increaſes that of the ice firſt formed. Ice produced in this manner is generally the hardeſt; it is ſmoother as well as more tranſparent, and in colour has a greater reſemblance to water. The caſe is not the ſame with the fragments of ice which are ſeen floating on rivers when their ice is broken; they have leſs conſiſtence, and are, as it were, of a ſpongy nature: the ſurface of them is rough and uneven; they are opake, and have a whitiſh colour; the lower part and edges of them are often covered with a pretty thick ſtratum of impure ice, filled with plants, ſand, earth, and other ſubſtances. See the reaſons of theſe phenomena in my *Principes de Phyſique*. No. 1082 et ſeq.

351. When water is mixed with foreign ſubſtances, a greater degree of cold is required to make it aſſume the ſtate of ice: this is the reaſon why ſalts, ſugar, and ſpirits retard the congelation of water. Theſe ſubſtances produce in water nearly the ſame effect as is produced in it by caloric, either free or combined; their particles being placed between the particles of the water, prevent them from uniting and maintaining their reſpective mobility, till the increaſing cold at length obliges theſe foreign ſubſtances, in ſome meaſure, to extravaſate, and to paſs into the part ſtill liquid. This is the reaſon why the center of theſe fragments of ice is more charged with ſuch ſubſtances than the reſt of the maſs.

352. The caſe is not the ſame with the cold which makes water freeze, as with the heat which brings it to the ſtate of ebullition. The temperature of boiling water never increaſes, however long it may be heated (338); but ice, when once formed, if expoſed to a cold which continues a certain time, and which goes on in an increaſing ratio, ſtill becomes colder. It may alſo be cooled artificially, by mixing with it ſalts or acids, and even ſpirituous liquors.

353. Though ice* be a ſolid and exceedingly hard body, it evaporates a great deal, and even much more than

---

* For further details on the phyſical properties of water, ſee my *Principes de Phyſique*, from art. 1040 to 1098 incluſively

than water in an equal time. This ariſes from the peculiar contexture of ice, which, by occupying more volume than water, and preſenting a larger and rougher ſurface, muſt, on that account, give more hold to the general cauſe of evaporation (343).

Simple Subſtances, and their Combinations.

354. It reſults from our knowledge of theſe aeriform fluids (53 *et ſeq.*), that there is a certain number of ſimple ſubſtances which enter into the compoſition of other bodies as principles, and which may be conſidered as their *elements.*

355. The object of chemiſtry, in ſubjecting to experiment the different bodies of nature, is that it may be able to examine ſeparately the ſubſtances which enter into their combination. This ſcience, in modern times, has made a rapid progreſs. Formerly, oil and ſalt were conſidered as the principles of bodies; but we ſhall ſee hereafter that they are compound ſubſtances; that ſalts are compoſed of an acid with ſome baſe; and that their ſtate of neutrality is the reſult of this union; we ſhall find that the acids themſelves are formed by the combination of an acidifying principle (oxygen) common to them all, and a radical peculiar to each, which eſtabliſhes a difference between them, and which conſtitutes

them an acid of one kind rather than of another; that the radicals of the acids themſelves are not always ſimple ſubſtances, and that, as well as the oily principle, they are often a compound of hydrogen and carbon. In the laſt place, we ſhall ſee that the baſes of the ſalts are often not more ſimple than the acids, as Berthollet has proved in regard to ammonia, which is compoſed of hydrogen and azote.

356. We cannot even be perfectly aſſured that what we at preſent conſider as ſimple bodies are ſo in reality: all that we can ſay is, that certain ſubſtances have ſuch a degree of ſimplicity, that it is impoſſible for us to decompoſe them.

357. The ſubſtances of this kind are,

Simple ſubſtances, which may be conſidered as the elements of bodies.	Caloric Oxygen Azote Hydrogen
Simple non-metallic ſubſtances, oxidable and acidifiable.	Carbon Sulphur Phoſphorus Muriatic radical Fluoric radical Boracic radical
Simple metallic ſubſtances oxidable and ſome of them acidifiable.	Gold Platina Silver Copper Iron

Simple

Simple metallic ſubſtances oxidable, and ſome of them acidifiable.	Tin Lead Mercury Biſmuth Cobalt Nickel Zinc Antimony Arſenic Manganeſe Tungſten Molybdena Titanium Chrome Tellurium
Simple, earthy, ſaliſiable ſubſtances	Lime Magneſia Barytes Alumine Silex Strontian Zirconia Glucina

Of Caloric.

358. Theſe ſimple ſubſtances may be combined with each other, and with other ſubſtances, in order to form compounds. All the bodies in nature are immerſed in caloric, which penetrates their parts throughout, and which fills up the intervals left between their moleculæ. In ſome caſes, the caloric is fixed in theſe bodies, and in ſuch a manner as even to contribute to their ſolidity; but it often ſeparates their

their moleculæ alſo, by exerciſing on them a repulſive force; and it is on its greater or leſs action or accumulation that the tranſition of bodies from the ſolid ſtate to the liquid, and from the liquid to the aeriform, depends.

359. The combination of caloric with

Oxygen *forms* Oxygen gas, or vital air
Azote — Azotic gas, or mephitic air
Oxygen and azote — Nitrous gas
Oxygen and carbon — Carbonic acid gas
Oxygen and the muriatic radical — Muriatic acid gas
Oxygen and the muriatic radical, ſurcharged with oxygen — Oxygenated muriatic gas
Oxygen and ſulphur — Sulphurous acid gas
Oxygen and the fluoric radical — Fluoric acid gas
Ammonia — Ammoniacal gas
Hydrogen — Pure hydrogen gas
Hydrogen and ſulphur — Sulphurated hydrogen gas
Hydrogen and phoſphorus — Phoſphorized hydrogen gas
Hydrogen and carbon — Carbonated hydrogen gas
Water — Aqueous gas
Alcohol, or ſpirit of wine — Alcoholic gas
Ether — Etherous gas.

Of Oxygen.

360. Oxygen is a ſubſtance diffuſed in great abundance throughout nature; it forms nearly a third in weight of our atmoſphere, and it is in the midſt of this immenſe reſervoir of it that animals and vegetables live and expand. Animals abſorb a great quantity

quantity of it by reſpiration; and it combines with animal and vegetable radicals, to convert them into acids: it acidifies all acidifiable ſubſtances; it is the real *acidifying principle*, without which no acid can exiſt. The reciprocal attraction exerciſed between oxygen and the different ſubſtances in nature, is ſuch that it is impoſſible to obtain it alone and diſengaged from every combination.

361. A certain number of conditions muſt be united, in order that a body may be oxygenated.— The firſt is, that the conſtituent moleculæ of this body muſt not exerciſe between themſelves an attraction ſtronger than that which they exerciſe on oxygen. If the moleculæ of this body do not poſſeſs this ſuperior force of attraction for oxygen, it may be communicated to them artificially, by expoſing them to heat; that is to ſay, by introducing into them caloric, which, ſeparating them from each other, diminiſhes the force of their reciprocal attraction, and allows them to exerciſe a more powerful one on the oxygen: oxygenation will then take place.

362. The degree of heat neceſſary to produce this phenomena is not the ſame for all ſubſtances:— ſome may be oxygenated at a temperature ſo low that we never find them but in an oxygenated ſtate. Of this kind is the muriatic radical, which never preſents itſelf to us ſimply, but always in the ſtate of an acid, which it has been hitherto impoſſible to decompoſe. To oxygenate the greater part of bodies,

and almoſt all ſimple ſubſtances, in general, it will be ſufficient to expoſe them to the action of the atmoſpheric air, and to raiſe them to the proper temperature. The temperature neceſſary to oxygenate lead, mercury, and tin, is not greater than that in which we live; but, on the other hand, a pretty high degree of heat is neceſſary to oxygenate iron and copper in the dry way, and when the oxygen is not aſſiſted by the action of humidity.

363. Sometimes the oxygenation takes place with great rapidity, and in that caſe is accompanied with heat, light, and even flame: ſuch is the combuſtion of phoſphorus in the air, and in oxygen gas. That of ſulphur is much leſs rapid. Tin, lead, and the greater part of the metals, oxidate ſlowly, and without the diſengagement of the caloric being ſenſible.

364. There is ſtill another method of oxygenating ſimple ſubſtances. Inſtead of expoſing them to oxygen united with caloric, the oxygen may be preſented to them in union with ſome metal for which it has little affinity: the red oxide of mercury is one of thoſe beſt fitted for accompliſhing this object, becauſe the oxygen in that ſtate adheres very little to the metal: it is diſengaged from it at that degree of heat at which glaſs begins to become red. The black oxide of manganeſe, the red oxide of lead, the oxide of ſilver, and almoſt all the metallic oxides, can, in a certain degree, produce the ſame effect.

365. Every metallic reduction or revivification, is an oxygenation of charcoal by a metallic oxide. The charcoal, by combining with the oxygen and caloric, eſcapes under the form of carbonic acid gas, and the metal remains pure and revived.

366. All combuſtible ſubſtances may be oxygenated alſo by combining them either with the nitrate of potaſh, or that of ſoda, or with the oxygenated muriate of potaſh. At a certain degree of heat the oxygen abandons the nitrate or the muriate, and combines with the combuſtible body, but with great violence. The reaſon is as follows: The oxygen, in combining with the nitrates, and particularly with the oxygenated muriates, enters along with a quantity of caloric almoſt equal to that neceſſary for conſtituting it oxygen gas. At the moments of its combination with the combuſtible body, all this caloric becomes ſuddenly free, and produces terrible detonations. This method of oxygenation, therefore, muſt not be attempted but with the utmoſt caution, and when very ſmall quantities of matter are employed.

367. There are different degrees of oxygenation: the firſt degree forms oxides; the ſecond forms weak acids; the third ſtrong acids; and the fourth hyperoxygenated acids.

368. The combination of oxygen with

		Degrees of Oxygenation.	
Simple Non-metallic Subſtances.	Caloric	—	*forms* oxygen gas
	Hydrogen	—	water
	Azote —	1, —	nitrous oxide, or the baſe of nitrous gas
		2, —	the nitrous, or red acid
		3, —	the nitric acid, or white *
		4, —	oxygenated nitric acid
	Carbon —	1, —	the oxide of carbon
		2, —	carbonous acid
		3, —	carbonic acid
		4, —	oxygenated carbonic acid
	Sulphur —	1, —	oxide of ſulphur. Soft ſulphur
		2, —	ſulphurous acid
		3, —	ſulphuric acid
		4, —	oxygenated ſulphuric acid
	Phoſphorus	1, —	oxide of phoſphorus
		2, —	phoſphorous acid
		3, —	phoſphoric acid
		4, —	oxygenated phoſphoric acid
	The Muriatic Radical	1, —	muriatic oxide
		2, —	muriatous acid
		3, --	muriatic acid
		4, —	oxygenated muriatic acid
	The Fluoric Radical	1, —	fluoric oxide
		2, —	fluorous acid
		3, —	fluoric acid
	The Boracic Radical	1, —	boracic oxide
		2, —	boracous acid
		3, —	boracic acid.

---

* Raymond thinks that the white nitric acid and the red, contain the ſame quantity of oxygen; and that the redneſs ariſes only from a weak combination of the baſe of the nitrous gas with the white acid. *Journal des Mines*, No. 22.

	The combination of oxygen with	Degrees of Oxygenation.	
Simple Metallic Subſtances.	Gold	1,	*forms* yellow oxide of gold
		2,	red oxide of gold, precipitate of Caſſius
	Platina	1,	yellow oxide of platina
	Silver	1,	oxide of ſilver
	Copper	1,	reddiſh brown oxide of copper
		2,	green and blue oxide of copper
	Iron	1,	black oxide of iron
		2,	yellow and red oxide of iron
	Tin	1,	grey oxide of tin
		2,	white oxide of tin
	Lead	1,	grey oxide of lead
		2,	yellow and red oxide of lead
	Mercury	1,	black oxide of mercury
		2,	yellow and red oxide of mercury
	Biſmuth	1,	grey oxide of biſmuth
		2,	white oxide of biſmuth
	Cobalt	1,	grey oxide of cobalt
	Nickel	1,	oxide of nickel
	Zinc	1,	grey oxide of zinc
		2,	white oxide of zinc
	Antimony	1,	grey oxide of antimony
		2,	white oxide of antimony
	Arſenic	1,	grey oxide of arſenic
		2,	white oxide of arſenic
		3,	arſenic acid
	Manganeſe	1,	black oxide of manganeſe
		2,	white oxide of manganeſe
	Tungſten	1,	oxide of tungſten
		2,	tungſtic acid
	Molybdena	1,	oxide of molybdena
		2,	molybdic acid
	Titanium	1,	oxide of titanium
	Chrome	1,	oxide of chrome
		2,	chromic acid.

369. In the mineral kingdom almoſt all the oxidable and acidifiable radicals ſeem to be ſimple ſubſtances; but in the vegetable kingdom there are ſcarcely any which are not compoſed of two ſubſtances, hydrogen and carbon: azote and phoſphorus are often joined with them, and the reſult is radicals with four baſes.

370. From theſe obſervations, it appears that the oxides and the animal and vegetable acids may differ from each other three ways: 1ſt, By the number of oxidable acidifiable principles which conſtitute their baſe; 2d, By the difference in the proportions of theſe principles; 3d, By the different degrees of oxygenation. This is more than ſufficient to account for the great number of varieties which nature exhibits to us.

371. It thence appears, therefore, that a great number of the vegetable acids can be converted into each other: nothing is neceſſary for this purpoſe, but to change the proportion of carbon and hydrogen, and to oxygenate them more or leſs: this Crell did in a number of very ingenious experiments; from which it reſults, that carbon and hydrogen, by the firſt degree of oxygenation, give tartareous acid; by a ſecond degree oxalic acid; and by a third, the acetous, or acetic acid.

372. The

372. The combination of oxygen with the compound radicals, ſuch as

The carbono-hydrous and hydro-carbonous radicals of the vegetable kingdom: ſuch are the radicals.	Tartaric	*forms*	tartareous acid	tartar
	Malic	—	malic acid	apples
	Citric	—	citric acid	lemons
	Pyro-lignic	—	pyro-ligneous acid	empyreuma of wood
	Pyro-mucic	—	pyro-mucous acid	empyreuma of ſugar
	Pyro-tartaric	—	pyro-tartareous acid	empyreuma of tartar
	Oxalic	—	oxalic acid	ſalt of ſorrel
	Acetic	—	acetous acid	vinegar
			acetic acid	radical vinegar
	Succinic	—	ſuccinic acid	volatile ſalt of amber
	Benzoic	—	benzoic acid	flowers of benjamin
	Camphoric	—	camphoric acid	
	Gallic	—	gallic acid	the aſtringent principle of vegetables
The carbono-hydrous or hydro-carbonous radicals of the animal kingdom joined to azote and often to phoſphorus: ſuch are the radicals.	Lactic	—	lactic acid	ſour whey
	Saccho-lactic	—	ſaccho-lactic acid	
	Formic	—	formic acid	ants
	Bombic	—	bombic acid	ſilk-worms
	Sebacic	—	ſebacic acid	tallow
	Lithic	—	lithic acid	calculus of the bladder
	Pruſſic	—	pruſſic acid	colouring matters of Pruſſian blue

Of Azote.

373. Azote is a principle diffuſed in great abundance throughout nature: when combined with caloric, it forms azotic or mephitic gas (128); which in volume is a fourth, and in weight a third leſs than atmoſpheric air. It always remains in the ſtate of gas at the temperature and preſſure of the atmoſphere which we experience; and we are unacquainted with any degree of compreſſion or cold capable of reducing it to the ſolid, or even to the liquid ſtate.

274. Azote

374. Azote is one of the eſſential conſtituent parts of animal matter; it is combined in them with carbon and hydrogen, and ſometimes with phoſphorus, the whole being connected by a certain portion of oxygen, which reduces them to the ſtate of oxide, or to the acid ſtate, according to the degree of oxygenation.

375. The nature of animal matters, therefore, may vary, like that of vegetable matters, three ways: 1ſt, By the number of the ſubſtances which enter into the combination of their radicals: 2d, By the difference in the proportion of theſe ſubſtances: 3d, By the different degrees of oxygenation.

376. The combination of azote with

Simple Subſtances.	Caloric	*forms*	azotic gas
		Degrees of Oxygenation.	
	Oxygen	1, 2, 3, 4,	nitrous oxide, or the baſe of nitrous gas nitrous acid, or red nitric acid, or white oxygenated nitric acid
	Hydrogen		ammonia
	Carbon Hydrogen and ſometimes Phoſphorus Oxygen		animal matters

Of Hydrogen.

377. Hydrogen is one of the conſtituent principles of water, and thence it has received its name:— it forms in the compoſition of water fifteen hundredth parts of its weight, while oxygen forms the other eighty-five parts.

378. The affinity of hydrogen for caloric is ſo great, that it conſtantly remains in the ſtate of gas at the degree of heat and preſſure in which we live; it is impoſſible, therefore, to procure it free from all combination, and conſequently we are unacquainted with the nature of this principle.

379. It is one of the moſt abundant principles in nature; for beſides entering into the compoſition of water, which is itſelf ſo abundant on the earth, it is one of thoſe principles which acts the moſt conſpicuous part in the vegetable and animal kingdoms, by its combination with different ſubſtances.

380. The combination of hydrogen with

Simple Subſtances.	Caloric	*forms*	hydrogen gas
	Oxygen	—	water
	Azote	—	ammonia, or volatile alkali
	Sulphur	—	the baſe of ſulphurated hydrogen gas
	Phoſphorus	—	the baſe of phoſphorized hydrogen gas
	Carbon	—	the baſe of carbonated hydrogen gas
		—	fixed and volatile oils
		—	the hydro-carbonous or, carbono-hydrous radicals of the vegetable kingdom
			and when azote and phoſphorus are joined with it,
		—	the hydro-carbonous, or the carbono-hydrous radicals of the animal kingdom.

Of Carbon.

381. Carbon appears to be a ſimple ſubſtance; for hitherto it has not been poſſible to decompoſe it. Modern experiments ſeem to prove that it exiſts completely formed in vegetables, in which it is combined with hydrogen, and ſometimes with azote and with phoſphorus, and that it aſſiſts to form in them compound radicals, which are afterwards carried to the ſtate of oxides or of acids, according to the proportion of oxygen united with them.

382. To obtain the carbon contained in animal or vegetable matters, nothing is neceſſary but to ex-

poſe

poſe them, firſt, to a moderate and then to a very ſtrong degree of heat, in order to decompoſe the laſt portions of water which the charcoal ſtrongly retains.

—

383. In theſe operations chemiſts employ retorts of earthen ware or porcelain, into which the combuſtible matters are introduced; and they are expoſed to a ſtrong heat in a reverberating furnace. The heat converts thoſe ſubſtances which are ſuſceptible of it into gas; and the carbon, which is more fixed, remains combined with a little earth and ſome fixed ſalts.

—

384. In the arts, the carbonization of wood is effected by a ſimpler and cheaper proceſs: the wood is cut into pieces nearly of the ſame ſize and length; theſe pieces are diſpoſed in heaps, and are covered with earth, in ſuch a manner as to prevent all communication with the air, except what is neceſſary to make the wood burn, and to drive off the oil and water formed during the combuſtion; they are then kindled, and when they have burnt a ſufficient time, the fire is extinguiſhed by ſtopping the holes which ſerved to introduce the air.

385. There are two methods of analyſing charcoal, viz. 1ſt, By its combuſtion in oxygen gas: 2d, Its oxygenation by the nitric acid. In both caſes it is converted into carbonic acid, and it leaves a reſiduum of lime, potaſh, and ſome neutral ſalts. It is not yet fully aſcertained whether the potaſh exiſts in charcoal before its combuſtion.

386. The combination of carbon not oxygenated

	Oxygen	*forms*	carbonic acid
with	Hydrogen	—	the carbono-hydrous radical fixed and volatile oils
	Iron	—	carburet of iron, or plumbage
	Zinc	—	carburet of zinc

Sulphur.

387. Sulphur is one of thoſe combuſtible ſubſtances which have the greateſt tendency to combination. At the common temperature of the atmoſphere it is concrete; and it does not liquify but at a heat ſeveral degrees higher than that of boiling water.

388. Sulphur is found completely formed, and almoſt in its utmoſt degree of purity in volcanic productions. It is found alſo, and much oftener, in the ſtate of ſulphuric acid, that is to ſay, combined with oxygen: it is in this ſtate when found in argil, gypſum, &c.

389. To extract the ſulphur of the ſulphuric acid united to theſe ſubſtances, it muſt be deprived of its oxygen. This may be effected by combining it at a red heat with carbon: the carbon takes from it its oxygen, and thence is formed carbonic acid, which, combining with caloric, diſengages itſelf in the ſtate of gas: the reſult then is a ſulphuret, which may be decompoſed by an acid: the acid unites

unites to the baſe of the ſulphuret, and the ſulphur is precipitated.

390. The combination of ſulphur not oxygenated with

	Degrees of Oxygenation.	
Oxygen	1, *forms*	oxide of ſulphur, or ſoft ſulphur
	2, —	ſulphurous acid
	3, —	ſulphuric acid
	4, —	oxygenated ſulphuric acid
Hydrogen	—	the baſe of ſulphurated hydrogen gas
Copper	—	ſulphuret of copper, or pyrites of copper
Iron	—	ſulphuret of iron, or pyrites of iron
Lead	—	ſulphuret of lead, or galena
Mercury	—	ſulphuret of mercury, or ethiops mineral; cinnabar
Zinc	—	ſulphuret of zinc, or blende
Antimony	—	ſulphuret of antimony, or crude antimony
Arſenic	—	ſulphuret of arſenic, or orpiment; realgar
Potaſh	—	ſulphuret of potaſh, or liver of ſulphur with a baſe of fixed vegetable alkali
Soda	—	ſulphuret of ſoda, or liver of ſulphur with a baſe of fixed mineral alkali
Lime	—	ſulphuret of lime, or liver of ſulphur with a calcareous baſe
Magneſia	—	ſulphuret of magneſia, or liver of ſulphur with a baſe of magneſia
Barytes	—	ſulphuret of barytes, or liver of ſulphur with a baſe of ponderous earth
Ammonia	—	ſulphuret of ammonia, or volatile liver of ſulphur; fuming liquor of boyle

Of

Of Phoſphorus.

391. Phoſphorus is a ſimple combuſtible ſubſtance; for no experiment gives us reaſon to think that it can be decompoſed. It was not known to the old chemiſts; and was diſcovered in 1667 by a German, named Brandt, who made a myſtery of his proceſs. A ſhort time after, Brandt's ſecret was diſcovered by Kunckel, who publiſhed the proceſs, and on that account it was called Kunckel's phoſphorus: a name which it ſtill retains.

392. It was from urine alone that this phoſphorus was firſt extracted; and though the method was deſcribed, particularly by Homberg, in the Memoirs of the Academy of Sciences for 1792, the Engliſh alone, for a long time, ſupplied this article to all Europe. It was not made in France till 1737, when it was prepared for the firſt time in the Botanical Garden, in the preſence of commiſſioners appointed by the Academy of Sciences.

393. At preſent it is extracted by a more convenient and economical proceſs, from the bones of animals, which are real phoſphate of lime. The ſimpleſt method, according to Gahn, Scheele, Rouelle, &c. is to calcine the bones of full grown animals until they are almoſt entirely white; to pound them and ſift them through a ſilk ſieve, and then to pour

over them ſulphuric acid diluted with water; but in leſs quantity than is neceſſary for diſſolving the whole quantity of matter.

394. The ſulphuric acid unites itſelf to the earth of the bones, and forms ſulphate of lime; by theſe means the phoſphoric acid is diſengaged, and remains in a free ſtate in the liquor. The liquor is then to be decanted, and the reſiduum being waſhed the water employed for this purpoſe muſt be added to the decanted liquor. The whole muſt then be evaporated, in order to ſeparate the ſulphate of lime which cryſtallizes in ſilky filaments, and you will thus obtain phoſphoric acid, under the form of white tranſparent glaſs; which, when reduced to powder, and mixed with a third of its weight of charcoal, and diſtilled, will yield good phoſphorus.

395. Phoſphorus is found in almoſt every animal ſubſtance, and in ſome plants, which, according to chemical analyſis, have an animal character. In this ſtate it is generally combined with carbon, hydrogen, and azote, from which there reſult radicals with four baſes. Phoſphorus inflames at the temperature of 104°.

396. The combination of phoſphorus not oxygenated with

	Degrees of Oxygenation.	
Oxygen	1, *forms*	oxide of phoſphorus
	2, —	phoſphorous acid
	3, —	phoſphoric acid
Hydrogen	—	phoſphuret of hydrogen, or the baſe of phoſphorized hydrogen gas
Azote	—	phoſphuret of azote
Carbon	—	phoſphuret of carbon
Sulphur	—	phoſphuret of ſulphur
Iron	—	phoſphuret of iron, called improperly *Siderit*

OF MINERAL SUBSTANCES.

397. The name of *mineral ſubſtances* is given to all thoſe found in the earth, and which form a ſolid part of our globe.

398. There are two kinds of them, eſſentially different, viz. *earthy and ſtony ſubſtances*, and *metallic ſubſtances.*

399. The former are the object of a ſcience called *Lithology* ; the latter, of a ſcience called *Metallurgy.*

LITHOLOGY.

400. The object of lithology is the ſtudy of earths and ſtones. Stones are dry, inodorous, and inſipid bodies,

bodies, which are only very little, or not at all ſoluble in water. Their ſpecific gravity never exceeds four times and a half that of water; and the greater part of them have a ſpecific gravity much leſs.

Primitive Earths.

401. By analyſing earths and ſtones, and freeing them from thoſe ſubſtances with which they are mixed, chemiſts have obtained principles that may be conſidered as *earthy elements*, or *primitive earths.*

402. Theſe principles, as far as yet known, are in number eight, viz. *lime*, *magneſia*, *barytes*, *alumine*, *ſilex*, *ſtrontian*, *zirconia*, and *glucina.*

403. Earth and ſtones ſeem all to be formed of three principles. We ſhall, therefore, examine ſeparately, what is the nature of each.

1. *Lime.*

404. *Lime* is rarely found in a pure ſtate, and free from the mixture of every other ſubſtance. It is contained in chalk, for chalk is a neutral ſalt, formed by the combination of lime with carbonic acid. The beſt proceſs for obtaining lime in its moſt perfect ſtate of purity, is as follows:

405. Waſh chalk in diſtilled water, brought to a ſtate of ebullition, and then diſſolve it in diſtilled acetous acid: this acid, by combining with the lime, expels the carbonic acid, which eſcapes under the gaſeous form; then precipitate the lime by carbonate of ammonia, for the acetous acid abandons the lime, in order to combine with the ammonia, and the lime is precipitated: waſh and calcine this precipitate, and the reſiduum will be *pure lime.*

406. Lime is ſoluble in water, but in very ſmall quantity; more than 600 parts of water are neceſſary to diſſolve one of it.

407. Lime has a pungent, hot, and acrid taſte; it turns blue vegetable colours green.

408. It takes up water with avidity: when thrown into this liquid it ſplits, ſwells up, acquires a larger volume, and excites a great deal of heat.

409. Lime diſſolves in acids without effervеſcence, but it excites heat. The borate of ſoda and the phoſphates of urine diſſolve it alſo.

410. Lime, when alone, is infuſible, even though the fire may be urged by oxygen gas, as has been proved by Lavoiſier; but if combined with acids, it forms a fuſible body, for lime is a ſalifiable baſe.

Of all theſe baſes it is that moſt abundantly diffuſed throughout nature.

2. *Magneſia.*

411. *Magneſia* has never yet been found free from every kind of foreign matter. To procure it in the utmoſt degree of purity, cryſtals of the ſulphate of magneſia (Epſom ſalt and that of Sedlitz), of which it forms the baſe, muſt be diſſolved in diſtilled water; and they are afterwards to be decompoſed by alkaline carbonates: the ſulphuric acid combines then with the alkalies, and abandons the magneſia, which combines with the carbonic acid, and is precipitated in this combination. This precipitate muſt then be calcined, in order to diſengage the carbonic acid; and what remains will be *pure magneſia.*

412. Pure magneſia is exceedingly white, tender, and, as it were, ſpongy. When perfectly pure, it is not ſenſibly ſoluble in water; but when combined with carbonic acid, it diſſolves in that liquid, and ſo much the better the colder the water.

413. Magneſia excites no ſenſible ſavour on the tongue; and in this reſpect it is greatly different from lime (407). It gives a light green colour to the tincture of turnſole.

414. The borate of ſoda and the phoſphates of urine diſſolve it with efferveſcence; and this affords

a very

a very ſimple method of diſtinguiſhing it from lime (409).

415. Lavoiſier proved by experiment that magneſia is as infuſible as lime (410).

3. *Barytes, or Ponderous Earth.*

416. *Barytes* has never yet been found pure and free from all combination. To obtain it of the neceſſary degree of purity, the following proceſs muſt be employed :—Pulverize ſulphate of barytes (ponderous ſpar) which is the moſt common combination of this earth, and calcine it in a crucible, with an eighth part of its weight of charcoal-duſt ; keep the crucible at a red heat for about an hour, and then pour the matter into water : the water will aſſume a yellow colour, and exhale a ſtrong odour of ſulphurated hydrogen gas : then filter the liquor, and pour into it muriatic acid ; there will be formed an abundant precipitate, which muſt be ſeparated by a ſecond filtration. The liquor that paſſes through the filter holds in ſolution muriate of barytes, which is formed by the addition of the muriatic acid. If you then add liquid carbonate of potaſh, the potaſh will combine with the muriatic acid, and the barytes with the carbonic acid, from which it may be freed by calcination : what then remains is pure barytes.

417. Barytes is under the pulverulent form, and exceedingly white. It is ſoluble in water, but in ſmall quantity : about 900 parts of water are neceſſary to diſſolve one of it. Barytes gives a very ſlight

tint of green to blue vegetable colours. Its ſpecific gravity is from 42 to 43000. Analyſis has proved that 100 parts of carbonate of barytes contain 62 of barytes, 22 parts of carbonic acid, and 16 parts of water.

418. The borate of ſoda, and ſtill better the phoſphates obtained from urine, diſſolve barytes with efferveſcence.

419. Barytes precipitates alkalies from their combinations with acids; but the pruſſiate of potaſh precipitates barytes from its combinations with the nitric and the muriatic acids. This ſerves to diſtinguiſh it from the other earths.

420. Barytes, when pure, is totally infuſible, as Lavoiſier found by experiment.

4. *Alumine, or Pure Argil.*

421. *Alumine* is found chiefly in the different kinds of clay, of which it forms the baſe, and where it is often mixed with ſilex. To obtain it very pure, ſulphate of alumine (alum) muſt be diſſolved in water, and afterwards decompoſed by alkaline carbonates. The alkali combines with the ſulphuric acid, which then abandons the alumine; and the latter combines with the carbonic acid abandoned by the alkali. The alumine muſt then be freed from this acid

acid by calcination; and after this proceſs it will remain pure.

122. Alumine abſorbs water with avidity, and becomes diluted in that liquid. It adheres ſtrongly to the tongue. The borate of ſoda and the phoſphates of urine diſſolve it.

423. Alumine, when expoſed to heat, becomes dry, ſhrinks, and cracks. By the action of the fire it acquires ſo great hardneſs as to ſtrike fire with ſteel: it is then no longer ſuſceptible of being diluted in water.

424. Alumine, even when perfectly pure, is completely fuſible in the fire, if urged by a current of oxygen gas. The reſult of its fuſion is a vitreous, opake, and very hard ſubſtance, which ſcratches glaſs in the ſame manner as precious ſtones do.

5. *Silex, or Vitrifiable Earth.*

425. *Silex* is almoſt in its ſtate of purity in rock-cryſtal: but to have it perfectly pure, one part of beautiful rock-cryſtal muſt be fuſed with four parts of pure alkali; the mixture muſt then be diſſolved in water, and precipitated by an exceſs of acid; the precipitate will be pure ſilex.

426. Pure ſilex is rough and harſh to the touch; its moleculæ, when diluted in water, are eaſily precipitated.

427. The fluoric acid diſſolves ſilex exceedingly well: it is alſo the ſolvent of glaſs. Alkalies diſſolve ſilex in the dry way, and with it form glaſs. Soda diſſolves ſilex with effervescence: the borate of ſoda diſſolves it ſlowly, and without any ebullition.

428. Silex cannot be fuſed by a burning lens; but by expoſing it to a fire, urged by oxygen gas, Lavoiſier produced a commencement of fuſion on its ſurface.

6. *Strontian.*

429. *Strontian*, as appears, was diſcovered by Dr. Hope, profeſſor of chemiſtry at Glaſgow. It is found in the ſtate of a carbonate, that is to ſay, combined with carbonic acid, in a vein of lead ore, at Strontian in Argyleſhire, in the weſtern part of Scotland. It has been found alſo combined with carbonic acid at Lead Hills, in the ſame country. Some of it has ſince been diſcovered at Montmartre in France, combined with ſulphuric acid; and it is probable that, by the reſearches of mineralogiſts, it will be found in other places *.

---

* The ſulphate has been found in conſiderable quantities in the neighbourhood of Briſtol. T.

430. Strontian was at firſt confounded with barytes; which indeed it reſembles in ſeveral reſpects, though it differs from it in others.

431. Carbonate of ſtrontian is decompoſed by the ſulphuric acid, and carbonic acid is diſengaged: the ſulphate of ſtrontian, thus obtained, is very little ſoluble in water.

432. Carbonate of ſtrontian diſſolves with effervefcence in the nitric and muriatic acids, and carbonic acid is diſengaged. Theſe nitrates and muriates of ſtrontian are not deliqueſcent, and are decompoſed by the ſulphates of lime, potaſh, and others.

433. The carbonate of ſtrontian may be deprived of its acid by calcination; its earth is then ſoluble in water, but in greater quantity in boiling than in cold water, for a part of it is precipitated by cooling.

Strontian, by theſe three properties, has a conſiderable degree of reſemblance to barytes; but it differs greatly from it in the following:

434. The carbonate of ſtrontian is lighter than carbonate of barytes: the ſpecific gravity of the latter is from 42 to 43000 (417); that of the carbonate of ſtrontian is only from 36 to 37000.

435. Strontian is either of a bright green colour, or tranſparent and colourleſs; that of barytes is a greyiſh white.

436. The carbonate of ſtrontian, with the nitric and muriatic acids, produces ſalts more ſoluble than thoſe produced by the ſame acids, and carbonates of barytes.

437. The carbonic acid adheres with ſomewhat leſs force to ſtrontian than to barytes.

438. The pruſſiate of potaſh does not decompoſe the nitrate of ſtrontian; but it completely decompoſes the nitrate of barytes.

439. Strontian, with the muriatic acid, forms a ſalt, which, when diſſolved in alcohol, makes it burn with a red flame; but barytes, with the ſame acid, forms a ſalt, which when diſſolved in alcohol, makes it burn with a yellowiſh flame.

440. The carbonate of ſtrontian may be taken internally, without any danger, and without the leaſt inconvenience: but that of barytes, if uſed in the ſame manner, produces violent vomiting, and ſoon after, death. This, without doubt, is a very ſtriking difference.

441. Analyſis has proved, that 100 parts of the carbonate of ſtrontian contain 62 parts of ſtrontian, 30 parts of carbonic acid, and 8 parts of water.

7. *Zirconia.*

442. *Zirconia* is a ſimple and primitive earth, lately diſcovered by Klaproth, in the jargon of Ceylon (528) of which it is a conſtituent part, and even the moſt abundant; for it has been found by analyſis, that 100 parts of the jargon of Ceylon contain 64 parts and a half of zirconia, 32 parts of ſilex, and two parts and a half of the oxide of iron.

443. To obtain zirconia pure, it muſt be united to the muriatic acid, with which it forms a muriate of zirconia; this muriate muſt be diſſolved in a large quantity of water, and the zirconia muſt be precipitated by potaſh: if it be carefully waſhed, and then brought to a red heat in a crucible, it will be perfectly pure.

444. Calcined zirconia has a white colour. It is rough to the touch, like ſilex (426); it has no ſavour, and is not ſoluble in water. Its ſpecific gravity is at leaſt 43000; that of diſtilled water being 10000.

445. Phoſphate of ſoda and ammonia, or the fuſible ſalt of urine, and alkalies, do not attack zirconia.

nia. When ſeparated from its ſolutions by cauſtic alkalies, this earth retains a pretty large quantity of water, which gives it the ſemi-tranſparency of horn; it has then the appearance of gum-arabic, both by its ſlightly yellow colour and its fracture and tranſparency.

446. Zirconia is ſuſceptible of uniting with carbonic acid; and Klaproth is wrong when he aſſerts the contrary. It unites alſo with the ſulphuric and nitrous acids: alkalies, and the firſt ſix primitive earths, ſeparate it from the latter acid.

447. Zirconia alone does not fuſe by the blowpipe; but it fuſes with the borate of ſoda, and gives a tranſparent colourleſs glaſs.

8. *Glucina.*

448. Glucina is a primitive ſimple earth, lately diſcovered by Vauquelin, in the *aigue-marine*, called *the Occidental*[*]. It is a white granulated earth, which efferveſces with acids. In 100 parts of this aigue-marine there are 14 of glucina.

449. *Glucina* is ſoluble in the carbonate of ammonia, as well as in the ſulphuric acid. In the latter caſe, the ſolution has at firſt a ſaccharine, and afterwards

---

[*] Journal des Mines, No. 43.

wards an aſtringent taſte. Its cryſtals are ſweet, like the ſolution.

450. *Glucina* has ſome reſemblance to alumine, as it is ſoft to the touch, adheres to the tongue, is light, diſſolves in potaſh, and is precipitated from its ſolution by ammonia. But it differs from alumine by its combinations with acids being exceedingly ſweet, by giving no alum when mixed with ſulphate of potaſh, by being entirely ſoluble in carbonate of ammonia, and by not being precipitated from its ſolutions by oxalate of potaſh and tartrite of potaſh, as alumine is.

451. The aigue-marine, which contains glucina, is a ſubſtance ſimilar to the emerald of Peru (535); it differs from it only by its colouring part, which is oxide of iron; whereas the colouring principle of the emerald of Peru is chrome (759).

452. It has been found by analyſis, that 100 parts of this ſtone contain 68 of ſilex, 15 of alumine, 14 of glucina, 2 of lime, and one of the oxide of iron.

OF STONES.

453. We have already ſaid (403) that all the kinds of earth and ſtones ſeem to have been formed of theſe *primitive earths*. Theſe earths are ſometimes combined with acids, and in that caſe form ſaline ſtones, which in ſome meaſure are earthy ſalts.

ſalts. Sometimes theſe earths are merely mixed together, which forms *ſtones properly ſo called.* Sometimes the latter are bound together by ſome cement, which forms *rocks*. There is alſo a fourth kind of ſtones; thoſe produced by the fire of volcanoes.

454. We ſhall divide ſtones, therefore, into four orders. The firſt comprehends *ſaline ſtones*; the ſecond, *ſtones properly ſo called*; the third *rocks*; and the fourth *thoſe ſtones* or *ſubſtances produced by volcanic fire*.

ORDER I.

Saline Stones.

455. This order comprehends all thoſe ſtones in which the primitive earths are combined with acids. It is on this account that they have been diſtinguiſhed by the name of *Saline Stones*. There are different kinds of them, diſtinguiſhed by the primitive earth which forms their reſpective baſes: and the ſpecies are diſtinguiſhed by the different acid combined with each baſe.

GENUS I.—*Saline Stones with a Baſe of Lime*.

456. *Combination of lime with carbonic acid.* This combination produces *carbonates of lime*, and *calcareous ſtones* in general. It is the moſt common of all, and

and comprehends all thoſe ſtones known under the generic name of *Lime-ſtone*; ſuch as calcareous ſpar, alabaſter, ſtalactites, marble, chalk, &c. Their principal characters are, 1ſt, That they effervefce with acids, which expel from them the carbonic acid; 2d, That they may be converted into lime by calcination, becauſe the carbonic acid is alſo expelled from them by heat.

457. Of the calcareous ſtones, ſome cryſtallize regularly, and in general exhibit rhomboids (*fig.* 15). Of this kind are the *calcareous ſpars*. Some of them alſo are priſmatic (*fig.* 16); and ſome pyramidal (*fig.* 17 *and* 18). Their ſpecific gravity is in general ſomewhat more than 27000. Analyſis has ſhewn, according to the experiments made by chemiſts, that in a hundred parts of theſe ſtones, there are from 34 to 36 parts of carbonic acid, from 53 to 55 parts of lime, and the reſt water.

458. Others cryſtallize only in a confuſed manner, as *alabaſter*; the ſpecific gravity of which is from 27 to 28000; and *ſtalactites*, the ſpecific gravity of which is no more than from 23 to 24000.

459. Others are found in rude maſſes, ſome of which are ſuſceptible of a beautiful poliſh, as *marble*; and ſome not, as *chalk*, and the *common ſtones* uſed for building. The ſpecific gravity of marble is from 26500 to 28500; and that of common ſtones is from 16000 to 24000. When ſtones of this kind have

ſufficient

ſufficient tranſparency, they produce double refraction.

460. We ſhall remark, that what renders old buildings ſo durable is, that the lime employed in the conſtruction of them has been converted into chalk, by abſorbing the carbonic acid diſperſed through the atmoſphere.

461. *Combination of lime with the ſulphuric acid.* The reſult of this combination is gypſum, ſelenite, and plaſter-ſtones. Theſe ſtones neither effervesce with acids, nor ſtrike fire with ſteel. The ſpecific gravity of the coarſe opake gypſum, called Plaſter-ſtone, is 21679; that of the other kinds of gypſum, is from 22000 to 23000. The moſt common cryſtallization of theſe ſtones is the decaedron, the ſurface of which is compoſed of two oppoſite oblique-angled parallelograms, to each of the ſides of which correſpond two trapeziums, placed ſo as to form a ridge (*fig.* 19).

462. If theſe ſtones, after being calcined and pounded, are beat up with water, they then form a thin mortar, which may be caſt into moulds of any form at pleaſure, and which hardens as it becomes dry. This is the ſubſtance employed for ſtucco-work, and various ornaments with which apartments are decorated. All the ſtones of this kind have the property of double refraction; and all of them, except coarſe gypſum, are impervious to water.

463. *Combination of lime with the fluoric acid.* This combination gives riſe to the *fluates of lime*, known under the name of *Sparry* or *Vitreous Fluors*. All theſe ſtones generally cryſtallize in cubes (*fig*. 20); they all have the tranſparency and beautiful colours of precious ſtones; and, like the oriental ſtones, they produce only ſingle refraction. Their ſpecific gravity is from 31000 to 31900.

464. Theſe ſtones do not efferveſce with acids, nor are they ſufficiently hard to ſtrike fire with ſteel. When pounded, they become phoſphoric.

465. The acid which, by its combination with lime, forms theſe ſtones, is a peculiar kind, called the *Fluoric Acid*, becauſe it is found completely formed in ſparry flour, which conſequently is a neutral ſalt. This acid poſſeſſes the ſingular property of taking up and diſſolving the ſiliceous earth, which enters as a conſtituent part into the compoſition of glaſs. Puymorin, therefore, employed this acid to engrave on glaſs, as the nitric acid is employed to engrave on copper.

466. Sparry flour may be fuſed by a ſtrong heat; but, owing to the property already mentioned, it ſtrongly attacks the crucible. It fuſes alſo without efferveſcence with mineral alkali, borate of ſoda, and phoſphates of urine.

467. *Combination of lime with the nitric acid.* The reſult of this combination is *nitrate of lime*, or *calcareous nitre.* This nitrate is nowhere found under a ſolid form. It is formed chiefly near inhabited places. The lixivium of old plaſter, produces it in great plenty: it is one of thoſe ſalts moſt abundant in the mother-water of ſaltpetre works. If made to cryſtallize, it exhibits cryſtals in the form of hexaedral priſms.

468. Nitrate of lime has a bitter diſagreeable taſte. It is exceedingly ſoluble in water; two parts of cold water are ſufficient to diſſolve one of this ſalt, and boiling water diſſolves more than its weight.

469. Nitrate of lime readily liquifies over the fire, and becomes ſolid on cooling. It is ſuſceptible of acquiring a phoſphoric property, for, if ſtrongly calcined, it appears luminous in the dark.

470. *Combination of lime with the muriatic acid.* The reſult of this combination is *muriate of lime*, or *calcareous muriate.* It exiſts chiefly in the waters of the ſea, and communicates to it that bitterneſs aſcribed to bitumen, which is not found in it.

471. Murate of lime is exceedingly ſoluble in water. One part and a half of cold water is ſufficient to diſſolve one part of the ſalt; warm water diſſolves more than its weight. By concentrating the

the ſolution, and keeping it in a cool place, it may be made to cryſtallize; it then produces a ſalt in the form of tetraedral priſms, terminated by pyramids of four planes.

472. Muriate of lime enters into fuſion at a moderate heat; but it is decompoſed with difficulty. By calcination, it acquires a phoſphoric property.

473. *Combination of lime with the phoſphoric acid.* The reſult of this combination is *phoſphate of lime.* This ſtone has been found in Eſtramadura in Spain: in that country it is ſaid there are whole hills of it, and the houſes and fences are built with it.

474. The phoſphate of lime is whitiſh, and conſiderably denſe; but it is not ſufficiently hard to ſtrike fire with ſteel: when thrown on burning coals, it burns quietly, and emits a beautiful green flame.

475. With the nitric and ſulphuric acids it exhibits the ſame phenomena as calcined bones, which are themſelves real phoſphate of lime. It may be deprived of its phoſphoric acid; and phoſphorus may be extracted from it by decompoſition, in the ſame manner as it is extracted from bones. It is on this account, no doubt, that this phoſphate has been called *Animal Earth.*

GENUS II.—*Saline Stones with a Baſe of Magneſia.*

476. In this genus are comprehended all thoſe ſtones which have *magneſia* for their baſe. Theſe ſtones have been known only ſince Dr. Black ſhewed that they ought not to be confounded with calcareous ſtones, from which they may eaſily be diſtinguiſhed, becauſe lime-water decompoſes them, and precipitates from them their magneſia. Theſe ſaline ſtones in general are pretty ſoluble in water, and all of them almoſt have a pretty ſtrong bitter taſte.

477. The combination of magneſia with the ſulphuric acid, produces *ſulphate of magneſia*, known under the name of Epſom or Sedlitz Salt (*fig.* 21) which is found in different kinds of mineral water. It has been found by analyſis, that 100 parts of this ſtone contain 19 of magneſia, 24 of ſulphuric acid, and 57 of water.

478. The combination of magneſia with the nitric acid, produces *nitrate of magneſia.* This ſubſtance decompoſes the muriates; but it is itſelf decompoſed by alkalies, and even by lime, which precipitate from it the magneſia.

479. The combination of magneſia with the muriatic acid, produces *muriate of magneſia*, which is found in the mother-water of ſalt-works. It has an exceedingly

exceedingly bitter taſte. Alkalies, lime, and barytes, precipitate its magneſia.

480. The combination of magneſia with carbonic acid produces *carbonate of magneſia.* This ſtone is ſoluble in water only in a very ſmall quantity: the action of heat deprives it of the water and acid which it contains, and the reſiduum is what is called *Calvined Magneſia.*

GENUS III.—*Saline Stones with a Baſe of Barytes.*

481. This genus conſiſts of all thoſe ſtones which have barytes for their baſe.

482. The combination of barytes with the ſulphuric acid produces *ſulphate of barytes*, known under the name of *Ponderous Spar.* This is the moſt uſual combination of barytes: it is the heavieſt of all the ſtones, for its ſpecific gravity is from 44228 to 44712. There are many metallic ores which are not ſo heavy. Ponderous ſpar is inſoluble in water: it is ſuſceptible of acquiring a phoſphoric quality by calcination.

483. The combination of barytes with carbonic acid, produces *carbonate of barytes*, known under the name of *Aerated Ponderous Earth.* Its ſpecific gravity is 42919. It appears by analyſis that 100 parts

of it contain 65 of barytes, 7 of carbonic acid, and 28 of water.

484. The combination of barytes with nitric acid produces *nitrate of barytes.* This ſubſtance is never found in a natural ſtate; but it may be eaſily procured by diſſolving pure barytes in nitric acid.—The ſulphuric and fluoric acids decompoſe it by taking the barytes from the nitric acid.

485. The combination of barytes with the muriatic acid produces *muriate of barytes.* It is never found native; but it may be obtained by diſſolving pure barytes in the muriatic acid. The muriate of barytes exhibits with acids almoſt the ſame phenomena as nitrate of barytes.

GENUS IV.—*Saline Stones with a Baſe of Alumine.*

486. In this genus are comprehended all thoſe ſtones which have *alumine* for their baſes.

487. The combination of alumine with the ſulphuric acid, produces *ſulphate of alumine,* known under the name of *Alum.* This is the moſt common combination of alumine. Alum has a ſtyptic taſte; it is very little ſoluble in water: 15 parts of that liquid are neceſſary to diſſolve one of it: magneſia, barytes, and alkalies, precipitate from it its alumine. Alum is employed for a great many purpoſes in the arts.

488. The combination of alumine with the carbonic acid produces *carbonate of alumine*, known under the name of *Chalky Argil.*

489. The combinations of alumine with the other acids are very little known : we only know that alumine diſſolved in nitric acid forms an aſtringent ſolution, and that the muriatic acid with alumine forms a gelatinous and deliqueſcent muriate.

GENUS V.—*Saline Stones with a Baſe of Silex.*

490. This genus is not very numerous. We are acquainted with no acid but the *fluoric*, capable of diſſolving *ſilex*, and it holds a greater quantity of it in ſolution when in the ſtate of gas, than when united with water. This acid, therefore, cannot be preſerved in glaſs bottles, becauſe it corrodes them, by taking away and diſſolving the ſiliceous earth, which enters into the compoſition of glaſs.

GENUS VI.—*Saline Stones with a Baſe of Strontian.*

491. In this genus we know only the combination of *ſtrontian* with the carbonic acid. This earth has been found in the ſtate of carbonate, at Strontian, in Argyleſhire in Scotland : it has been found alſo combined with carbonic acid at Lead-Hills, in the ſame country. It has lately been found

likewiſe at Montmartre, combined with ſulphuric acid; and it is probable that it will be found in other places. This carbonate is of a tranſparent, or bright green colour (*ſee art.* 429 *et ſeq.*).

GENUS VII.—*Stones with a Baſe of Zirconia.*

492. *Zirconia* has been found only in the jargon of Ceylon, and was diſcovered by Klaproth. It is one of the conſtituent parts of that ſtone, and even the moſt abundant, for 100 parts of jargon contain 64¼ of zirconia (*ſee art.* 442 *et ſeq.*).

GENUS VIII.—*Stones with a Baſe of Glucina.*

493. *Glucina* has been found only in the *occidental aigue-marine.* It was diſcovered by Vauquelin. It is one of the conſtituent parts of that ſtone, 100 parts of which contain 14 of glucina. It is a white granulated earth, and effervefces with acids (*ſee* 448 *et ſeq.*).

ORDER II.

Stones properly ſo called.

494. The pure and ſimple primitive earths, ſuch as thoſe above deſcribed (401 *et ſeq.*) are rarely found

alone at the ſurface of the earth; they are generally mixed there with each other, and form maſſes more or leſs voluminous, and of greater or leſs hardneſs, according to the nature of the earths which are mixed together, and of the foreign matters combined with them. This is what forms *ſtones properly ſo called.*

495. In theſe mixtures there is generally one earth predominant; that is to ſay, preſent in greater quantity than any of the reſt, or at leaſt which ſeems to give a character to the whole. It is this which determines the genera: the ſpecies are diſtinguiſhed by the different principles of which they are conſtituted.

GENUS I.—*Calcareous Mixtures.*

496. This genus comprehends thoſe ſtones in which limeſtone is predominant. There are many ſtones of this kind, all of which efferveſce with acids: the different principles united to the limeſtone conſtitute the ſpecies.

497. *Magneſia* united to limeſtone is a very common mixture; for all calcareous ſtones almoſt contain this ſubſtance.

498. *Barytes* is alſo found ſometimes united to limeſtone: this mixture forms another ſort of calcareous ſtone, which is more ponderous than the others.

499. *Alumine* mixed with the carbonate of lime forms *marl*, more or leſs fat, according to the different proportions of the two conſtituent principles.

500. *Iron* is very often mixed with limeſtone; when united with it in a large quantity, this union forms calcareous iron ore.

501. *Silex* is ſometimes mixed with it, but this mixture is rare: it is known under the name of *Stellated Spar*; it appears radiated. In 100 parts of this ſtone there are 30 of ſilex, and 66 of the carbonate of lime.

502. *Bitumen* is alſo ſometimes mixed with limeſtone. This mixture is known under the name of *Swineſtone*. It abounds in Lower Languedoc.

GENUS II.—*Barytic Mixtures*.

503. As barytes is little known, theſe mixtures are very rare: we are acquainted with no more than two. *Hepatic-ſtone* is one of them. When rubbed, it exhales a ſtrong fetid odour. This ſtone in 100 parts contains 33 of barytes, 38 of ſilex, 17 of alum, 7 of gypſum, and 5 of petroleum.

504. Another mixture of this genus is compoſed of carbonate of barytes, ſilex, and iron. It has a ſparry texture, and is found to be inſoluble in acids.

GENUS III.—*Magneſian Mixtures.*

505. The principal character of all theſe mixtures is, that they are greaſy and ſoft to the touch. Though not very hard, ſome of them are ſuſceptible of a fine poliſh: they may be worked by the lath, and made to aſſume any figure whatever.—Others of them conſiſt of fibres, which have a conſiderable degree of flexibility. None of theſe mixtures efferveſce with acids.

506. The ſtones of this kind are *ſerpentine*, *ſteatites*, *pot-ſtone*, *aſbeſtus*, *mountain-cork* or *foſſil-leather*, *amianthus*, and *talc*. The three firſt may be cut with the chiſel, or by the lath, and particularly pot-ſtone, which is made into veſſels that ſtand heat, and are ſuperior for uſe to our beſt glazed earthen-ware. *Aſbeſtus* and *foſſil-leather* are compoſed of fibres not ſuſceptible of calcination. They are exceedingly flexible, and when pulled aſunder, ſeem to tear rather than to break. The *amianthus* is compoſed of fibres ſo flexible, that they may be made into cloth. They are entirely incombuſtible. The beſt mode of bleaching this cloth when dirty, is to throw it into the fire. *Talc* is ſoft and ſaponaceous to the touch: it is compoſed of thin, ſmooth, brilliant laminæ, which may be eaſily ſeparated in the direction of their planes. Muſcovy talc is that produced in the largeſt maſſes. It is

ſaid

ſaid that ſome leaves of it have been found eight feet ſquare.

Genus IV.—*Aluminous Mixtures.*

507. All theſe mixtures have very little durability, if we except one kind, called the *Horn-Stone*, which is ſometimes ſo hard as to ſtrike fire with ſteel.

508. The ſtones of this kind are the *micas*, *horn-ſtone*, *argil*, *ſchiſts*, and *zeolites*. The micas are ſoft to the touch, but not greaſy; which forms a diſtinction between them and talc. They often enter into the compoſition of the granites. Horn-ſtones, which are conſidered as argillaceous ſtones mixed with quartz, have a cloſe grain, and are difficult to be pounded.

509. The character of the *argils* is, that they adhere ſtrongly to the tongue. In the fire they dry, become hard, and ſhrink: they become diluted in water, and with that liquid form a paſte, which may be made to aſſume every kind of figure. They form the baſis, therefore, of all kinds of earthenware. Argil is employed alſo in fulling-mills, for ſcouring cloth.

510. *Schiſts* are compoſed of leaves either very apparent, which may be eaſily ſeparated in the direction

tion of their planes, as is the caſe with ſlates; or little apparent, and which can be ſeparated with difficulty, as is the caſe in regard to *hones* and *whetſtones*. All theſe ſtones are permeable to water. Slate is employed in covering houſes.

511. The *zeolites*, for the moſt part, are ſuſceptible of being reduced into a jelly by acids. Some of them are ſo hard as to ſtrike fire with ſteel; others are not. They are all permeable to water.

GENUS V.—*Siliceous Mixtures.*

512. All ſtones of this kind have ſufficient hardneſs to ſtrike fire with ſteel. Theſe ſtones are *gems*, or *precious ſtones*, *rock-cryſtal*, or *quartz*, *felſpar*, *ſilex*, the *chryſopraſus*, *lapus lazuli*, *jaſper*, and *ſchorl*.

Gems.

513. *Gems*, or *precious ſtones*, are exceedingly numerous. They are diſtinguiſhed by their hardneſs, weight, colour, and ſplendor, as well as by their property of producing ſingle or double refraction. As their colour, of all their characters, is the moſt apparent, it is according to this character that we ſhall divide them.

Red Gems.

514. Theſe are the *ruby, the vermillion, garnet,* and *giraſol.*

515. The ruby is a tranſparent ſtone; the colour of which is more or leſs red. It is diſtinguiſhed into four kinds, viz. the *oriental ruby*, the *ſpinel ruby*, the *balaſs ruby*, and the *Brazilian ruby.*

516. The *oriental ruby* has a purpliſh or crimſon red colour: in hardneſs it is almoſt equal to the oriental ſapphire (530), and even little inferior to the diamond (540). It appears to be unalterable: it withſtands the moſt violent heat without fuſing,* and when expoſed to it, it retains its poliſh, its weight, and its colour, the laſt of which is given to it by chrome (759). Its cryſtals are formed of two very long hexaedral pyramids, joined at their baſes, and each compoſed of ſix faces, which are iſoſceles triangles (*fig.* 22). Its ſpecific gravity is 42833. It produces only ſingle refraction.

517. The *ſpinel ruby* is of a red colour, which ſeems to be mixed with a ſlight tint of orange. It is

---

[*] By ſome experiments lately publiſhed, it appears that the oriental ruby is fuſible. This was effected by the London Philoſophical Society. See Philoſophical Magazine, vol. viii. p. 28.—Trans.

is much inferior in hardneſs to the preceding (516). Its cryſtalline form (*fig.* 23) reſembles that of the oriental diamond (542) except that its faces are planes, whereas thoſe of the diamond are ſomewhat convex. The ſpecific gravity of this ruby is 37600. It produces only ſingle refraction.

518. The *balaſs ruby* appears to be only a variety of the former (517) from which it differs merely by its colour, being of a brighter red. It cryſtallizes, like it in octaedra (*fig.* 23) and produces only ſingle refraction. Its ſpecific gravity is 36458. The colouring principles of theſe three rubies (516, 517, 518) is chrome (759).

519. The *Brazilian ruby* is of a red colour, inclining to yellow. It cryſtallizes in tetraedral priſms terminated by ſummits, the faces of which are ſcalene triangles, or in octaedral priſms, terminated by ſummits with four faces, which are trapezoides (*fig.* 25). In hardneſs it is almoſt equal to the ſpinel ruby (517). Its ſpecific gravity is 35311. It produces double refraction.

520. The *vermillion* is of a very bright crimſon red colour. With the form of its cryſtals I am not acquainted. Its ſpecific gravity is 42299. It produces only ſingle refraction. In both theſe reſpects it reſembles the oriental ruby. It ſurpaſſes the ſpinel ruby in hardneſs (517).

521. The *garnet* is of a very dark red colour, and has very little tranſparency. Its cryſtals are rhomboids of 12 faces (*fig.* 26) or trapezoides of 24 faces (*fig* 27) or they are compoſed of 36 faces, twelve of which are rhombs, and the other twenty-four lengthened hexagons (*fig.* 28). The garnet fuſes in the fire, but it retains its colour. Its ſpecific gravity is 41888. It produces double refraction. Another ſort of this ſtone, called the *Syrian Garnet*, is of a very bright red, inclining to violet. Its ſpecific gravity is ſomewhat leſs than the former, being only 40000. It produces double refraction.

522. The *giraſol* is a white tranſparent ſtone, with a ſlight tint of red and a ſtill ſlighter of blue.—We are very little acquainted with this ſtone; and the form of its cryſtals is unknown. Its ſpecific gravity is 40000. It appears to hold a middle rank between the ruby and the oriental ſapphire; and, like theſe ſtones, it produces only ſingle refraction.

Yellow Gems.

523. Theſe are the *topaz*, *hyacinth*, and *jargon of Ceylon*. Of the topaz there are three kinds; the *oriental topaz*, the *Brazilian topaz*, and the *Saxon topaz*.

524. The *oriental topaz* is of a very beautiful and very bright golden yellow colour. Its cryſtals

(*fig.*

(*fig.* 22) have a reſemblance to thoſe of the oriental ruby (516), and it poſſeſſes nearly the ſame degree of hardneſs. It ſtands the violence of the fire without fuſing, and retains its colour and tranſparency. Its ſpecific gravity is 40106. It produces only ſingle refraction. There is one variety of this ſtone which differs only by its colour being yellow inclining to green: it has therefore been called the *Piſtachio Topaz.* Its ſpecific gravity is ſomewhat greater than that of the former, being 40615.

525. The *Brazilian topaz* is of a darker golden yellow colour than the oriental (524). Its cryſtallization reſembles that of the Brazilian ruby (*fig.* 24 and 25): it has alſo the ſame hardneſs. In the fire it aſſumes a red colour; and it then has a perfect reſemblance to the Brazilian ruby: it is therefore ſuppoſed that theſe two ſtones are the ſame. The ſpecific gravity of this topaz is 35365; it produces double refraction.

526. The *Saxon topaz* is of a yellow colour, not very bright. It cryſtallizes in octaedral priſms, the ſummits of which are compoſed of twelve lateral inclined faces of different figures, and a thirteenth horizontal face, which is hexagonal (*fig.* 29). Its ſpecific gravity is 35640. It produces double refraction. This topaz is found ſometimes colourleſs. In that caſe its ſpecific gravity is only 35535.

527. The *hyacinth* is of an orange colour, or a red inclining to yellow. The form of its cryſtals is of a tetraedral rectangular priſm, or priſm of four planes, terminated at each of its extremities by a ſummit of four rhomboidal faces, which correſpond to the edges of the priſm (*fig.* 30). In hardneſs it is not ſuperior to rock-cryſtal. It fuſes in the fire, and loſes its colour. Its ſpecific gravity is 36873. It produces double refraction.

528. The *jargon of Ceylon* is a ſtone lately diſcovered. In colour it approaches near to the hyacinth; but it differs greatly from that ſtone by the form of its cryſtallization, its hardneſs, its reſiſtance to the action of heat, its weight, and one of its conſtituent parts which is zirconia (442), a primitive earth not found in the hyacinth, which proves that it is a diſtinct ſpecies. The form of its cryſtals is a rectangular tetraedral priſm, terminated at each of its extremities by a ſummit of four faces, which are iſoſceles triangles (*fig.* 21). In hardneſs it is nearly equal to the oriental ſtones. It reſiſts the action of heat, without ſuſtaining any injury. Its ſpecific gravity is 44161. It is the heavieſt of all the gems. It produces a double refraction, which cauſes the two images to be at a great diſtance from each other. In 100 parts of this ſtone there are 64½ of zirconia, 32 of ſilex, and two of the oxide of iron.

Blue Gems.

529. Theſe are the *ſapphire*, and the *aigue-marine*. There are two kinds of the ſapphire, viz. the *oriental ſapphire*, and the *Brazilian*. There are alſo two kinds of the *aigue-marine*, the *oriental* and the *occidental*.

530. The *oriental ſapphire* is of a beautiful ſky-blue colour: its cryſtalline form (*fig.* 22) is the ſame as that of the oriental ruby (519). In hardneſs it is inferior only to the diamond (540). It reſiſts the violence of the fire without fuſing, but it loſes its colour. Its ſpecific gravity is 39941. It produces only ſingle refraction.

531. The *Brazilian ſapphire* differs a great deal from the former, by being inferior in hardneſs. Its colour is a dark blue. Its cryſtalline form is an enneaedral priſm (*fig.* 31) or a priſm of nine planes, three of which are pentagonal, and the other ſix ſmall parallelograms, terminated at each extremity by a ſummit of three faces, pentagonal at one of the extremities, and hexagonal at the other, the edges of one of the ſummits correſponding with the faces of the other. Its ſpecific gravity is 31307. It produces double refraction.

532. The *aigue-marine* is of a blue colour, inclining to green. The oriental, called alſo the *Beryl*, is exceedingly bright. Its cryſtalline form is an octaedral priſm (*fig.* 29.) ſimilar to that of the Saxon topaz (526). In hardneſs it is nearly equal to the garnet (521). Its ſpecific gravity is 35489. It produces double refraction.

533. The *aigue-marine*, called the Occidental, has leſs ſplendor than the preceding. Its cryſtalline form is a regular hexaedral priſm, terminated at each of its extremities by a hexagonal plane (*fig.* 16). In hardneſs it is not ſuperior to rock-cryſtal (547). It fuſes in the fire, and loſes its colour. Its ſpecific gravity is 27227. It was in this ſtone that Vauquelin diſcovered a primite earth, to which he gave the name of *Glucina* (448). According to the experiments of that chemiſt, it is compoſed of 68 parts of ſilex, 15 of alumine, 2 of lime, 1 of iron, and 14 of this new earth.

Green Gems.

534. Theſe are the *emerald of Peru*, and the *chryſolite*, of which there are two kinds, viz. the *Brazilian*, and that of *the jewellers*.

535. The *emerald of Peru* is of a green colour, more or leſs dark: thoſe of a bright green are the moſt eſteemed. The cryſtalline form of this ſtone (*fig.*

(*fig.* 16) is the ſame as that of the occidental *aigue-marine* (533). Its hardneſs is ſomewhat leſs than that of the garnet (523). It reſiſts the violence of the fire without fuſing, and retains its colour, which is communicated to it by *chrome* (739). Its ſpecific gravity is 27755. It produces double refraction.

536. The *chryſolite* is of a yellow colour, inclining to green. Its hardneſs is ſomewhat leſs than that of the emerald of Peru. It reſiſts the fire without fuſing, but it often loſes its colour. It produces double refraction.

537. The *Brazilian chryſolite* is of a beautiful golden colour, inclining a very little to green. Its cryſtals (*fig.* 16) reſemble thoſe of the emerald of Peru (535). Its ſpecific gravity is 26923.

538. The *chryſolite of the jewellers*, which, according to Vauquelin, is real phoſphate of lime, is of a yellow colour, mixed with green. Its cryſtalline form is a hexaedral priſm, the edges of which are more or leſs flatted, and terminated at each extremity by a ſummit of ſix faces (*fig.* 32). Its ſpecific gravity is 27821.

The Diamond.

539. The *diamond* ought certainly to be claſſed among the precious ſtones; but it is ſo different from all

all thoſe above deſcribed, that it deſerves to be made the ſubject of a ſeparate article. Its combuſtibility is a property entirely peculiar to itſelf: the diamond indeed burns in the ſame manner as phoſphorus, and diſappears without leaving any veſtiges of it behind; but for this purpoſe the contact of the air is neceſſary, as it is for the combuſtion of all other bodies. Guyton Morveau has made a ſeries of ingenious experiments on the combuſtion of the diamond, the principal reſults of which are as follow.

The diamond is pure carbon; for, 1ſt, By oxygenating it to a certain degree, it may be converted into charcoal; but charcoal is nothing elſe than oxygenated *carbon:* 2d, By oxygenating the diamond to ſaturation, it becomes converted into carbonic acid, without any reſiduum; and carbonic acid is nothing elſe than carbon oxygenated to ſaturation.

To perform theſe two operations on the diamond, you muſt firſt expoſe it to a very violent degree of heat, in order to deſtroy the adheſion of its parts, otherwiſe it never would be poſſible to convert it either into charcoal or into carbonic acid. By the firſt operation it aſſumes a black plumbeous colour.

The adheſion of the parts being once deſtroyed, if you expoſe the diamond to a heat equal to about 18 or 20 degrees of Wedgewood's pyrometer (3417 or 3677 of Fahrenheit) it acquires the ſame degree of oxidation as charcoal would do if expoſed to the action of a very ſtrong heat in a cloſe veſſel, and by theſe means it becomes real charcoal.

If the diamond be expoſed to a higher temperature, about 30 pyrometric degrees, or 4977° of Fahrenheit, it becomes ſaturated with oxygen: it then acquires a degree of oxidation equal to that of carbonic acid. At this temperature indeed the diamond produces carbonic acid itſelf.

From theſe reſults it appears that the diamond is *pure carbon*: when combined with a quantity of oxygen equal to that which charcoal contains, the reſult is real charcoal. If means could be found, 1ſt, to deprive charcoal of all its oxygen; 2d, to give proper adheſion to the parts of the carbon which, in combination with oxygen conſtitutes charcoal, the reſult would be *real diamond.*

540. The diamond is the hardeſt of all bodies: it can be cut only by itſelf, diamond-duſt being the only ſubſtance capable of attacking it.

541. The diamond has a great degree of tranſparency: it is the moſt beautiful and moſt brilliant of all the precious ſtones. It produces only ſingle refraction; but its refractive power is ſtronger than that of any other body; it ſeparates the colours better, and this is the reaſon why it ſparkles with ſo much luſtre, eſpecially in the light of the ſun, or

even that of a candle. There are two kinds of the diamond, the *oriental* and the *Brazilian*, which differ only in their form.

542. The *oriental diamond* cryſtallizes in octaedra, compoſed of two pyramids, having four equilateral triangular faces a little convex, united by their baſes (*fig*. 23). This form is ſometimes modified into a figure of twenty-four faces (*fig*. 33) and ſometimes even of forty-eight faces (*fig*. 34) all triangular and ſomewhat convex. The ſpecific gravity of the oriental diamond is 35212.

543. The *Brazilian diamond* cryſtallizes in dodecaedra, the twelve faces of which are rhombs a little convex (*fig*. 26). Its ſpecific gravity is 34444.

544. There are ſeveral varieties of the diamond, which differ from each other only by their colour. I have ſeen ſome of a roſe-colour, and others red, orange, yellow, green, blue, and black.

545. *A Table of the Specific Gravity and Hardneſs of the Precious Stones, in decreaſing Order.*

Gravity.		*Hardneſs.*
1 Jargon of Ceylon	44161	1 The Diamond
2 Oriental Ruby	42833	2 The Oriental Sapphire
3 Vermilion	42299	3 The Oriental Ruby
4 Garnet	41888	4 The Oriental Topaz
5 Oriental Topaz	40106	5 The Jargon of Ceylon
6 Giraſol	40000	6 The Vermilion
7 Oriental Sapphire	39941	7 The Spinel Ruby
8 Emerald of Peru	37755	8 The Balaſs Ruby
9 Spinel Ruby	37600	9 The Brazilian Topaz
10 Hyacinth	36873	10 The Brazilian Ruby
11 Balaſs Ruby	36458	11 The Brazilian Sapphire
12 Saxon Topaz	35640	12 The Giraſol
13 Oriental Aigue-marine	35489	13 The Saxon Topaz
14 Brazilian Topaz	35365	14 The Garnet
15 Brazilian Ruby	35311	15 The Oriental Aigue-marine
16 Diamond	35212	16 The Emerald of Peru
17 Brazilian Sapphire	31307	17 The Chryſolite
18 Occidental Aigue-marine	27227	18 The Occidental Aigue-marine
19 Chryſolite	26923	19 The Hyacinth,

Certain Method of knowing the Precious Stones, and of diſtinguiſhing them from each other.

546. To diſtinguiſh with certainty the precious ſtones from each other, attention muſt be paid to four things: 1ſt, Their ſpecific gravity; 2d, Their hardneſs; 3d, Their colour; 4th, Their property of producing ſingle or double refraction. Their cryſtalline form alſo would be exceedingly proper

for

for this purpoſe, but it is not always poſſible to diſtinguiſh it.

There are ſome ſtones which have common properties, but which poſſeſs others that eſtabliſh a difference between them. Thus, for example, the *oriental ruby* (516) and the *red diamond* (544) have the ſame colour and the ſame refraction; but they have neither the ſame gravity nor the ſame hardneſs: the ruby is heavier, but has leſs hardneſs than the diamond. The caſe is the ſame with the *oriental topaz* (524) and the *yellow diamond* (544) as well as with the *oriental ſapphire* (530) and the *blue diamond* (544): they have the ſame refraction and the ſame colour reſpectively; but the diamond has more hardneſs, and leſs ſpecific gravity than the topaz and the ſapphire.

The giraſol (522) has the ſame refraction, and nearly the ſame colour as the *roſe-coloured diamond* (544); but it is much heavier, and has leſs hardneſs.

The *red diamond* (544) and the *Brazilian ruby* (519) have nearly the ſame gravity and the ſame colour; the caſe is the ſame with the *yellow diamond* (544) and the *Brazilian topaz* (525), as well as with the *blue diamond* (544) and the *beryl* (532); but beſides the difference which exiſts between theſe ſtones and the diamond, in regard to hardneſs, they have

have not the ſame refraction. That of the diamond is ſingle, and that of the other ſtones double.

The *Brazilian ruby* (519) in colour, hardneſs, and gravity, approaches near to the *ſpinel ruby* (517); but the latter produces only ſingle refraction, while the Brazilian ruby produces double.

The *jargon of Ceylon* (528) is almoſt as hard as the *oriental topaz*, but it differs from it by its colour and gravity, and by producing double refraction.

Red ſparry fluor (463) and the *red diamond*, have the ſame colour, the ſame power of refraction, and nearly the ſame gravity: but they greatly differ from each other by their hardneſs; which, in the diamond is immenſe, while in the ſparry fluor it is ſo little, that it is not capable to ſtrike fire with ſteel. If the other coloured diamonds be compared with the ſparry fluors of analogous colours, the caſe will be found to be the ſame.

It is impoſſible, therefore, to find two ſtones, one of them oriental and the other not oriental, having the ſame colour, the ſame refraction, the ſame gravity, and the ſame hardneſs; and hence we are furniſhed with the certain means of never being deceived.

Rock-Cryſtal and Quartz.

547. *Rock-cryſtal* and *quartz* ſeem to be the ſame ſtone. The name of rock-cryſtal is given to that which is cryſtallized, and of quarz to that which is in a rude maſs. The form of theſe cryſtals is a hexaedral priſm, terminated at one of its extremities, and ſometimes at both, by a ſummit, compoſed of ſix triangular faces (*fig.* 35). In hardneſs they are inferior to all the other gems (512). They produce double refraction.

Rock-cryſtal is a ſtone in which the *ſilex* (425) approaches neareſt to the ſtate of purity, and where it is the leaſt mixed with foreign bodies; for, according to the analyſis of Bergman, 100 parts of rock-cryſtal contain 93 of ſilex, 6 of alumine, and one of lime. Rock-cryſtal is often coloured with iron, and it is diſtinguiſhed by different names, according to the ſhade of colour it has received. The yellow is called *Bohemian Topaz*, the green the *Falſe Emerald*, the violet the *Amethyſt*, the blue the *Water-Sapphire*, the reddiſh-brown the *Hyacinth of Compoſtella.* The ſpecific gravity of theſe ſtones is generally a little more than 26500.

Quartz enters into the compoſition of *granite. Free-ſtone* is of the ſame nature as quartz. It has a granulated fracture, for it is compoſed of ſmall grains

of

of quartz, which have very little adheſion. All kinds of it almoſt are permeable by water.

Felſpar (*Spathum Scintillans*).

548. Every kind of felſpar changes its colour, more or leſs, according to the direction in which the rays of light fall upon it. When this ſtone cryſtallizes, it aſſumes the form of a tetraedral inclined priſm; the ſurface of which is compoſed of ſix planes, four of them rectangular, and two rhomboidal (*fig.* 36). It cryſtallizes alſo in the form of a hexaedral priſm, or priſm of ſix planes, two of them hexagonal, and four quadrilateral, terminated at each extremity by a ſummit of two pentagonal faces (*fig.* 37). There are ſome alſo in the form of a decaedral priſm, or priſm of ten planes, two of which are large octagons, and eight ſmall trapeziums, terminated at each extremity by a ſummit of ſix faces, one a large enneagon, another a large heptagon, and four ſmall trapezoides (*fig.* 38).

Felſpar is inferior in hardneſs to quartz (547): when ſufficiently tranſparent, it produces double refraction. It fuſes by the action of heat, and forms white enamel. It is one of the conſtituent parts of porcelain. It is the *petuntze* of the Chineſe. It enters alſo into the compoſition of *porphyry* (561) *ſerpentine* (562) the *ophite* (563) *granitell* (564) and *granite* (565).

549. We may introduce into this claſs *adamantine ſpar*, which approaches nearer to the preceding in its appearance and fracture, but which differs from them conſiderably by its great hardneſs, its form, and gravity. It is ſo exceedingly hard, that it may be employed, as ſome aſſert, to cut the diamond (539). The form of its cryſtals is a hexaedral priſm, or priſm of ſix planes, two large and four ſmall. Its ſpecific gravity is 38732.

Flint.

550. *Flint* is a ſtone which is ſo hard as to ſtrike fire with ſteel : when ſufficiently tranſparent, it produces double refraction. Its ſpecific gravity, in general, is about 26000. Among the different kinds of flints, ſome change their colour according to the direction of the rays of light ; and others do not. Of the former there are three, the *opal*, the *cat's eye*, and the *fiſh-eye*.

1. The *opal* exhibits all the priſmatic colours, with more or leſs force and brilliancy.

2. The *cat's eye* is a ſtone which ſeems to throw out rays of light, ſimilar to thoſe which proceed from the eyes of cats ; ſome of them are grey, yellow, &c.

3. The *fiſh eye* is generally white, and, as it were, foliaceous. The ſubſtance of it has a conſiderable degree

degree of reſemblance to the cryſtalline humour of a fiſh's eye when boiled.

551. The kinds of flints which do not change their colour, according to the direction of the rays of light, exhibit tints of more or leſs brightneſs, and are ſuſceptible of a fine poliſh. We are acquainted with eight kinds of them, viz. *common flint*, *petro-ſilex*, *agate*, *calcedony*, *cornelian*, *ſardonyx*, the *jade*, and the *praſium*.

1. *Common flint* poſſeſſes very little tranſparency. All the different kinds of it have a dark dull colour, and are concave or convex on the fracture. They do not fuſe in the fire, but are calcined, and become white.

2. The diſtinguiſhing character of *petro-ſilex* is its ſemi-tranſparency, ſimilar to that of wax. It becomes white in the fire, like the common flint, but it is more fuſible, as it runs without any addition.

3. *Agate* has a ſmooth ſhining fracture, and is ſuſceptible of a very fine poliſh: it is variegated with every kind of colour, except bright red, orange, and green. When expoſed to heat, it loſes its colour, and becomes opake, but without fuſing.

4. The *calcedony* has a milky, or nebulous, ſemi-tranſparency. Every kind of it is ſuceptible of a fine

a fine poliſh. Theſe ſtones are white, intermixed ſometimes with tints of red, yellow, and blue.

5. The *cornelians* are all, either entirely or in part, of a beautiful red colour; but they loſe their colour in the fire, and become opake. They are all ſuſceptible of a fine poliſh.

6. The different kinds of the *ſardonyx* are, entirely or in part, of an orange-colour, more or leſs dark: they loſe their colour in the fire, or become opake, but without fuſing. They are all ſuſceptible of a fine poliſh.

7. The diſtinguiſhing character of the *jade* is, that when poliſhed, it ſeems greaſy to the touch, as if rubbed over with oil. The different kinds of this ſtone exhibit different colours; ſome of them are white, others green, and ſome olive.

8. The *praſium* is of a ſemi-tranſparent leek-green colour. It is ſuſceptible of a fine poliſh.

The Chryſophraſium.

552. The *chryſophraſium* is ſemi-tranſparent, and of an apple-green colour: it loſes its colour in the fire, and becomes opake. In hardneſs it is ſuperior to quartz (547).

Lapis

Lapis Lazuli.

553. *Lapis lazuli* is of a beautiful ſky-blue colour, ſometimes mixed with white, and is entirely opake. It is ſometimes mixed with pyrites, from which it has been concluded that it contains gold. If expoſed to a ſtrong heat, it fuſes, and forms a ſort of whitiſh glaſs: when calcined it diſſolves in acids, into a kind of jelly. Lapis lazuli, when pulverized, forms that valuable colour known under the name of *Ultramarine.*

Jaſper.

554. *Jaſper* is a ſtone which exhibits every variety of colour: it is exceedingly hard, and ſuſceptible of a very beautiful and durable poliſh: when expoſed to the action of heat, it does not fuſe. We are even aſſured by Wedgewood that it becomes hard. Its ſpecific gravity is not always the ſame, and varies from 23000 to 28000.

Schorl.

555. *Schorl* is a hard ſtone, fuſible in a moderate fire, without any addition. Its cryſtals exhibit ſo

great

great variety in regard to form, appearance, texture, ſtructure, &c. that there is reaſon to preſume that ſtones of a different nature have been claſſed under this denomination.

Schorl in general is opake; ſome kinds, however, are tranſparent: ſuch as the *Brazilian emerald*, the *peridot*, the *turmalin*, &c. All theſe ſtones produce double refraction.

The colour of ſchorl is various; ſome kinds are black, others violet, and ſome green.

Some kinds of the black ſchorl cryſtallize in priſms of ſix planes, terminated at each extremity by a ſummit, compoſed of three rhomboidal faces (*fig.* 39); others in a priſm of eight planes, terminated at each extremity by a ſummit of two hexagonal faces (*fig.* 40); and ſome in a priſm of nine planes, terminated by a ſummit of three pentagonal faces at one extremity, and three hexagonal ones at the other (*fig.* 31). The black ſchorl in rude maſſes, which does not cryſtallize, is known under the name of *Ancient Black Baſaltes*; another kind, black and opake, is diſtinguiſhed by the name of *Sparry Schorl.*

Violet ſchorl is tranſparent, and of a fawn-colour, inclining to violet. Its cryſtals are rhomboidal parallelopipeda, very much compreſſed, two of the oppoſite edges of which form facets (*fig.* 41).

Green ſchorl, known under the name of the *Brazilian Emerald*, is tranſparent, and of a dark green colour. Its cryſtalline form is a priſm of nine planes, like that of the black ſchorl (*fig.* 31) but badly defined, and difficult to be determined.

The ſchorl known under the name of *Peridot*, is very tranſparent, and of a yellowiſh green colour, more or leſs dark: it cryſtallizes like the preceding (*fig.* 31).

That known under the name of Turmaline, is of a blackiſh brown colour, but tranſparent when not too thick: it cryſtallizes like the preceding (*fig.* 31). Turmalines are found in Ceylon, Brazil, and in Tyrol. They all become electric when heated.

There is one kind of ſchorl, known under the name of *Cruciform Schorl*, or *Croſs-ſtone*, the cryſtals of which are compoſed of two hexaedral priſms, which croſs each other ſometimes at right angles (*fig.* 24) and ſometimes in ſuch a manner as to form acute angles (*fig.* 25). The ſpecific gravity of ſchorl is not always the ſame; it varies from 29225 to 34529.

Schorl enters into the compoſition of porphyry (561) ſerpentine (562) the ophite (563) granitelles (564) and granite (565).

GENUS VI.—*Mixture of Strontian.*

556. We are acquainted with no other combination of *ſtrontian* than that with the carbonic acid: of this nature is that found at Strontian, and at Lead-Hills in Scotland: it forms, therefore, a carbonate of a bright green colour, or tranſparent and colourleſs. Some of it, however, has been ſince found at Montmartre in France †, combined with ſulphuric acid (*ſee art.* 429).

GENUS VII.—*Mixtures of Zirconia.*

557. *Zirconia* has never yet been found but in the jargon of Ceylon (528) of which it forms one of the conſtituent parts, and where it is united to ſilex and a little of the oxide of iron (*ſee art.* 442).

GENUS VIII.—*Mixtures of Glucina.*

558. The only ſtone in which glucina has been found is the *aigue-marine*, called the *Occidental* (533) in which it was diſcovered by Vauquelin, and where it is combined with ſilex, alumine, a little lime, and a little ir *ſee art.* 448).

---

† And near Briſtol in England.—T.

ORDER III.

ORDER III.

Rocks.

559. The eight primitive earths (402) viz. lime, magneſia, barytes, alumine, ſilex, ſtrontian, zirconia, and glucina, differently mixed, form the ſtones of which we have ſpoken; and theſe ſtones, differently united and connected by any kind of cement, form thoſe ſtony maſſes called *Rocks*. We have already mentioned the characters by which each of theſe ſtones is diſtinguiſhed: they may be eaſily known in theſe mixtures, for they are merely mixed, and not changed in their nature.

560. We ſhall here notice only ſeven of theſe mixtures, which are thoſe moſt frequently found, and in the largeſt maſſes: theſe ſeven are *porphyry* (561) *ſerpentine* (562) *ophites* (563) *granitelles* (564) *granite* (565) *mill-ſtones* (566) and *flint* (567).

561. I. *Porphyry* is compoſed of felſpar (5;8) in ſmall fragments, of ſchorl (555) and a kind of cement which unites all the parts, and which, in ſome meaſure, forms the baſe of porphyry. This cement appears to be jaſper (554). Porphyry is exceedingly hard and difficult to be cut; it is, however, ſuſceptible of a fine poliſh. Some kinds of it are red, and others green. The ground of the colour is determined by the jaſper.

562. II. *Serpentine* is compoſed of the ſame ſubſtances as porphyry (561); the only difference is, that the felſpar (548) is in larger fragments. The colour of ſerpentine is various; ſome kinds are green, others violet; ſome yellow, and ſome black: the principal colour is always determined by the jaſper (554).

563. III. The *ophite* is compoſed of only two ſubſtances, viz. black ſchorl (555) known under the name of *Ancient Black Baſaltes* (555) interſperſed with greeniſh felſpar (548) which forms in it long ſpots. This ſtone has conſiderable hardneſs.

564. IV. *Granitell* is alſo compoſed of two ſubſtances, black ſparry ſchorl (555) and white felſpar, mixed with ſome of the green felſpar (548). The only difference then between the granitelles and the ophite is, that the ſchorl which enters into the compoſition of the former, is not of the ſame kind as that in the latter (563).

565. V. *Granite* is compoſed of felſpar (548) ſchorl (555) and quartz (547): in ſeveral kinds there is alſo mica (508). The colour of granite is exceedingly various; it is exceedingly hard, difficult to be worked, and never receives a fine poliſh.

566. VI. *Mill-ſtones* are exceedingly hard, and more or leſs porous. With the ſtones which enter into their compoſition, we are not much acquainted. The names of theſe ſtones ſufficiently indicate the purpoſe to which they are applied.

567. VII. *Flint* is a hard opake ſtone, ſuſceptible of a beautiful poliſh. It appears to be compoſed of concentric ſtrata, and has conſiderable brilliancy on its fracture. Flints are never found in continued quarries like the other ſtones; they are found detached and diſperſed throughout the fields. When joined by any kind of cement, they form *pudding-ſtones:* they become decompoſed in the air, for they are found for the moſt part covered with a cruſt of a ſofter nature than the interior part. Their colour is exceedingly various: ſome of them are ſpotted, and variegated with veins; others exhibit the reſemblance of plumes, and even of plants.

ORDER IV.

Stones or Subſtances produced by Volcanic Fire.

568. Theſe ſubſtances are thoſe produced by volcanoes ſtill in a ſtate of eruption, or which are found near extinguiſhed volcanoes: of this kind are *pumice-ſtone*, *lava*, and *baſaltes*.

569. I. *Pumice-ſtone* is real glaſs in the form of ſmall greyiſh white, and exceedingly brilliant filaments. Theſe filaments always leave vacuities of greater or leſs ſize between them; which occaſions great variation in its ſpecific gravity. In general, it is about 9000.

570. II. *Lava* is that burning matter which runs down in prodigious quantities from volcanoes in a ſtate of eruption, ſpreads itſelf over the fields, and often extends to a great diſtance.

This matter is real glaſs, which appears black by reflection; and which, by its tranſparency, inclines to violet. Its ſpecific gravity, when very denſe, is 23480.

571. III. *Baſaltes* is blackiſh and opake. By the action of heat it may be converted into glaſs of a very beautiful black colour. It often cryſtallizes in priſms of three, four, five, ſix, or ſeven planes. Of ſome kinds, ſuch as that known under the name of *Touchſtone*, the grain is exceedingly fine. Its ſpecific gravity is from 24153 to 28642.

572. When theſe ſubſtances, produced by volcanic fire, have ſufficient tranſparency, they produce ſingle refraction. *

---

* For farther details reſpecting theſe earths and ſtones, ſee my *Principes Elementaires de l'Hiſtoire Naturelle et Chymique des Subſtances Minerales.*

METALLURGY.

573. The object of *metallurgy* is the ſtudy of metallic ſubſtances. Theſe ſubſtances are the heavieſt of all the natural bodies: they have the property of fuſing in the fire, and of thereby acquiring ſplendor: they afterwards become hard on cooling, and their upper ſurface aſſumes a convex form.

574. Nature rarely preſents to us theſe ſubſtances in a ſtate of purity. If we except gold and ſometimes ſilver, it has combined them with various other ſubſtances, which conceal and change their metallic properties. The metals thus concealed and buried in the earth form ores, from which the metallic part muſt be extracted. The ſcience which teaches us to extract the metal from the ore is called *Docimaſia*.

575. Of the metallic ſubſtances, ſome are malleable and ductile, that is to ſay, they have the property of being extended under the hammer; others are not malleable, or very little ſo. The former are the Metals properly ſo called; the latter the Semi-Metals. We ſhall divide them into two orders.

ORDER I.

The Metals.

576. To be acquainted with the metals, is of great importance to us; they are ſo frequently uſed in commerce, and are employed ſo many different ways in the arts, that it is highly neceſſary we ſhould have a thorough knowledge of them.

577. The metals are in number ſeven, viz. *gold*, *ſilver*, *platina*, *copper*, *iron*, *tin*, and *lead*.

578. Several of them remain fixed, even when expoſed for a long time to the moſt violent heat, without experiencing any change in their weight, or any ſenſible alteration. Theſe are called *Perfect Metals*. The others remain fixed only to a certain degree, beyond which they alter, combine with oxygen (360) and are changed into a kind of earth, called *Metallic Oxide* (368). The latter are called *Imperfect Metals*. We ſhall divide them into two genera.

GENUS I.—*The Perfect Metals.*

579. We give the name of Perfect Metals to thoſe which poſſeſs, in an eminent degree, the property of being extended, lengthened, and flattened, without

without cracking or breaking when ſtruck with a hammer, drawn through a wire drawing-plate, or ſtrongly compreſſed between rollers. Theſe metals remain fixed when expoſed for a long time to a violent heat, without experiencing any change in their weight or ſenſible alteration: of this kind are *gold*, *ſilver*, and *platina*.

1. *Gold.*

580. *Gold* is a yellow metal, which does not poſſeſs very great ſplendor; it has little elaſticity (794) and it is not very ſonorous (795) hard (791) or tough (793). Of all the metals it is the moſt ductile (789) and has the greateſt fixity when expoſed to heat (788). Its ſpecific gravity (796) is inferior only to that of platina (596). It adheres with more ſtrength to mercury than any of the other metals (801).

581. As gold is not liable to become tarniſhed, it is employed for making ornaments and articles of dreſs: but the moſt important uſes to which it is applied, are for plate, money, and jewellery.

582. In mines gold is found, for the moſt part, in a native ſtate, either cryſtallized in octaedra, or in fibres and filaments of different lengths; or in laminæ, diſperſed throughout ſome matrix; or in ſcales ſcattered among ſand or earth: it is found

alſo ſometimes in irregular maſſes; and in that ſtate is called *Pepite d'Or*. Some pieces of a large ſize have been found in Mexico and Peru. I have ſeen one from the cabinet of Count d'Ons-en-Bray, which weighed about ſixteen pounds.

583. Gold, when expoſed to a ſtrong heat, becomes red before it fuſes; when exceedingly red, it is very near the point of fuſion; when fuſed, however long it may be kept in that ſtate, it experiences no alteration. I have, however, ſeen it volatilized in the focus of Trudaine's lens; but this volatilization did not alter it in any manner, for it gilded a plate of ſilver which I held over it.

584. The nitro-muriatic acid, or oxygenated muriate (807) is the real ſolvent of gold. This ſolution is of a yellow colour; it gives a purple tint to the ſkin. If the ſolution be properly concentrated, it produces yellow cryſtals, like the topaz (523) and which aſſume the form of truncated octaedra. Theſe cryſtals are real *muriate of gold*.

585. If ammonia, or volatile fluor alkali, be poured into a ſolution of gold, the yellow colour diſappears; but, at the end of ſome time, there are diſengaged from it ſmall flakes, which ſtill become yellower, and are gradually precipitated to the bottom of the veſſel. This precipitate, when dried in the ſhade, is known under the name of *Fulminating Gold*.

Gold. Ammonia is eſſential to its fulmination, as has been proved by Berthollet.

586. Gold is precipitated from its ſolution by ſeveral of the metals and ſemi-metals: ſuch as ſilver, copper, iron, lead, tin, mercury, biſmuth, and zinc. Tin precipitates it immediately, and forms *the purple of Caſſius.*

587. Gold may be allayed with all the metals, and with ſeveral of the ſemi-metals. With mercury it forms a paſte employed for gilding in *or moulu.*

2. *Silver.*

588. *Silver* is of a white colour, pure, and brilliant. Next to gold, it is the moſt eſteemed of all the metals. Next to gold and platina, it is the moſt ductile (789) and that which has the greateſt fixity in the fire (788). It is alſo, next to copper, the moſt ſonorous (795). In elaſticity (794) and tenacity, it is inferior only to iron, copper, and platina. It has leſs hardneſs than iron, platina, or copper. Its ſpecific gravity is inferior to that of platina, gold, mercury, and lead; but it is ſuperior to that of all the other metals and ſemi-metals.

589. Silver is employed chiefly for making plate, and for different kinds of money.

590 In mines, ſilver is found ſometimes in a native ſtate; it is then called *Virgin-Silver.* In this ſtate it is either cryſtallized in ramifications, and known under the name of *Virgin-Silver in Vegetation,* or it is found in fine flexible threads, or in thin laminæ, diſperſed throughout ſome matrix, or in maſſes of greater or leſs ſize. Silver, however, is oftener found mineralized with other ſubſtances.

591. Silver, when expoſed to heat, becomes red before it fuſes; but it fuſes ſoon after (790). When fuſed, it may be ſubjected to a very ſtrong heat without alteration. In the focus of Trudaine's lens it has indeed been volatilized; but it whitened plates of gold which I held over it. Some chemiſts aſſert that they have ſeen ſilver vitrified: but is it not rather poſſible that they may have vitrified ſome portion of the ſupports?

592. The nitric acid is the real ſolvent of ſilver*. The metal firſt becomes oxidated by combining with a portion of the oxygen of the acid, and afterwards diſſolves in it. It appears that metals do not diſſolve in acids until they have been oxidated. The nitric acid can diſſolve a quantity of ſilver equal to more than the half of its weight; it is then precipitated in cryſtals, which are *nitrate of ſilver,*

---

* This is not quite correct. The preſence of water is indiſpenſably neceſſary. See Philoſophical Magazine, vol. vii. p. 83.

and which are known under the name of *Lunar Cryſtals*. A ſolution of theſe cryſtals is exceedingly cauſtic, and corrodes the epidermis. This nitrate of ſilver, melted and poured into moulds, forms *lapis infernalis*. It muſt be made with very pure ſilver.

593. As the muriatic acid adheres ſtrongly to its oxygen, it does not oxidate ſilver, and conſequently it cannot diſſolve it: but the oxygenated muriate, by its exceſs of oxygen (200) eaſily oxidates ſilver, and afterwards, having become ſimple muriatic acid, diſſolves it very ſpeedily.

594. Silver is precipitated from its ſolution in nitric acid by lime-water, by alkalies, and by ſome metals, as copper and mercury. When ſilver is precipitated by mercury, it forms a kind of vegetation, known under the name of *Arbor Dianæ*.

595. Silver, as well as gold, may be made to acquire a fulminating property, but in an inferior degree. To form fulminating ſilver, you muſt employ Berthollet's proceſs, which is as follows:— Diſſolve cupelled ſilver in nitric acid, precipitate the ſilver from this ſolution by lime-water, and having decanted the liquor, expoſe the precipitate for three days to the air; then dilute the dried precipitate in ammonia, where it will aſſume the form of a black powder: if you then decant the liquor again,

and dry this powder in the air, you will have *fulminating ſilver.*

The contact of ſome burning body is neceſſary to make gun-powder detonate; and, to produce the ſame effect on fulminating gold, it muſt be expoſed to a certain degree of heat; but the contact of the ſmalleſt body, and even cold, is ſufficient to make fulminating ſilver detonate. It is a ſubſtance really not tangible, and therefore it muſt be kept in the capſule in which it has been made. Great caution is requiſite in preparing it, and ſtill more in performing experiments with it.

3. *Platina.*

596. *Platina* is a white metal, but of a duller colour, and leſs brilliant than ſilver. It is heavier than gold (796) and conſequently it is the heavieſt of all bodies. When expoſed to heat, it exhibits nearly the ſame fixity as gold (788); it experiences no alteration either in the air or in water. Its ductility is not inferior to that of gold (789). Next to iron, it is the hardeſt of metals (791). Its tenacity and elaſticity are inferior to thoſe only of iron and copper (793, 794). It is more ſonorous than gold or lead (795) but it is leſs ſo than all the other metals.

597. Platina is found in its mines in the ſtate of ſmall grains, or ſcales, of a livid white colour; it is always combined with iron, and is then ſuſceptible of being attracted by the magnet. In this ſtate it has very little ductility; but when completely purified from every foreign ſubſtance, it is ſufficiently ductile to be drawn through a plate, and even into a very fine wire without breaking. It is exceedingly difficult to render it very pure, and to work it like other metals.

598. Platina is abſolutely infuſible with an ordinary heat (790). When expoſed in the focus of Trudaine's lens, it ſhewed only the commencement of fuſion, ſo that the grains were a little cemented to each other. Lavoiſier, however, fuſed theſe grains with great eaſe, by exciting the fire with a current of oxygen gas. By this proceſs he fuſed *purified platina* with ſtill greater eaſe. In this ſtate of purification its ſpecific gravity is 195000; but when rolled, its gravity is 220690.

599. Platina is ſoluble only in the nitro-muriatic acid, or oxygenated muriate. It is precipitated from its ſolution by alkalies. A ſolution of muriate of ammonia poured into a ſolution of platina, forms in it an orange-coloured precipitate, which is a ſaline ſubſtance entirely ſoluble in water. This property, which the muriate of ammonia has of precipitating platina,

platina, furniſhes a very ſimple method for diſcovering whether gold is alloyed with platina.

600. *Platina* is a metal valuable, on account of its hardneſs, the fine poliſh of which it is ſuſceptible, and its unalterability. It is employed for making the ſpecula of teleſcopes, which, becauſe they never loſe their poliſh, are ſuperior to any other kind. It poſſeſſes alſo another good property, which is, that it undergoes very little change in its dimenſions by changes of temperature. On this account it was employed with great advantage in meaſuring an arc of the meridian, comprehended between Dunkirk and Barcelona.

GENUS II.—*The Imperfect Metals.*

601. The name of *Imperfect Metals* is given to thoſe which, like the perfect metals, poſſeſs ductility, but which remain fixed in the fire only to a certain degree; beyond that degree they become altered, combine with oxygen, and are converted into a ſort of earth, called *Metallic Oxide.* There are reckoned to be four imperfect metals, viz. *copper*, *iron*, *tin*, and *lead*.

1. *Copper.*

602. Copper is of a red or orange colour, and exhibits brilliancy on its fracture. It is the moſt

ſonorous of all the metals (795). In elaſticity and toughneſs it is inferior only to iron (793, 794). It has leſs hardneſs than iron or platina, but it is harder than any of the other metals (791). In ductility it approaches near to tin (789). It may be reduced to very thin leaves, by making it paſs between rollers; and may be drawn out into exceedingly fine wire. Its ſpecific gravity is ſomewhat greater than that of tin. Of all the imperfect metals, it is that which remains longeſt fixed in the fire.

603. Copper is found ſometimes native in its mines, or in laminæ with a matrix of quartz, or in compact maſſes of conſiderable ſize. It is, however, oftener found mineralized with other ſubſtances and forming an ore. This ore is ſometimes decompoſed and reduced to the ſtate of oxide. The reſult in this caſe is what is called *Mountain Green*, *Mountain Blue*, *Malachite*.

604. Copper does not fuſe until ſome time after it has been brought to a ſtate of ignition, and at a degree of heat not much greater than that neceſſary to fuſe gold (790). If kept in a ſtate of fuſion, it is in part volatilized.

605. The nitric acid diſſolves copper with effervеſcence, and the ſolution has a blue colour. The acid firſt oxidates the metal, a large quantity of

nitrous gas (189) is then diſengaged, and the copper afterwards diſſolves.

606. The ſulphuric acid does not diſſolve copper, unleſs when concentrated, and very warm: blue cryſtals of a rhomboidal form, known under the name of *Sulphate of Copper*, are the reſult. Lime and magneſia both decompoſe this ſulphate. The precipitate thence produced is of a bluiſh white colour; but when dried in the air it becomes green. Ammonia alſo precipitates the copper from this ſulphate of a whitiſh blue colour; but the precipitate diſſolves almoſt as ſoon as formed, and the reſult is a beautiful blue liquor, called *Celeſtial Water*.

607. The muriatic acid does not diſſolve copper but when concentrated and in a ſtate of ebullition: the ſolution is green, and produces pretty regular priſmatic cryſtals of a beautiful graſs-green colour, the taſte of which is cauſtic, and exceedingly aſtringent.

608. The acetous acid does not diſſolve copper, becauſe it does not contain a ſufficient quantity of oxygen to produce a commencement of oxidation in the metal; it only corrodes it, and the reſult is *verdet*, or *verdigriſe*; which, being diſſolved in vinegar, forms cryſtallized acetite of copper, known under the name of *Cryſtals of Venus*: but the acetic acid, or radical vinegar, diſſolves copper when preſented to it, even in the ſtate of metal; becauſe, as it contains more oxygen than the acetous acid, it is capable of firſt oxidating, and then diſſolving it.

609. Iron precipitates copper from its ſolutions: for this purpoſe nothing is neceſſary but to immerſe the iron in the ſolution; the acid ſeizes on the iron and abandons the copper, which is then precipitated. This copper, thus precipitated, is called *Copper of Cementation.* This proceſs is employed by jugglers, who often boaſt of being able to convert iron into copper; but it may be eaſily ſeen in what this tranſmutation conſiſts.

610. Copper may be alloyed with the greater part of the metals and ſemi-metals. As an alloy of ſilver (588) renders it more fuſible, this mixture is employed as ſolder for ſilver plate. Copper when alloyed with tin (642) forms *bronze,* a metal employed for making bells, cannon, and ſtatues; when alloyed by cementation with the oxide of zinc, called *Calamine* (695) it forms *braſs* (611); when alloyed by fuſion with zinc, it forms *Similor,* or *Manheim Gold*; with arſenic (707) it forms *White Tombac*; with biſmuth (671) a reddiſh white mixture; and with antimony (700) a violet-coloured mixture.

611. There are two ſorts of copper employed in the arts, viz. pure copper, and braſs (610) which is a mixture of three parts of very pure copper and one part of zinc (692). Zinc changes the colour of copper to a beautiful yellow, approaching near to that of gold.

612. Copper is employed for making the pipes of water-conduits, bathing-tubs, kettles, ſtills, &c.; it is uſed alſo for kitchen-utenſils, but very improperly, for as theſe veſſels are liable to be corroded by the ſalts and acids uſed in the preparation of food, they often become dangerous, and may thus make us ſwallow ſlow poiſon. Kitchen-utenſils of tinned iron are far preferable, becauſe iron poſſeſſes no qualities injurious to health.

613. Braſs is employed for various ornaments, as it can be eaſily gilt: moſt of our articles of furniture are decorated with it. It is uſed alſo for ſtatues, and for bas-reliefs; when not gilt, its ſurface at length becomes covered with a greeniſh cruſt, as may be ſeen on old ſtatues and coins, the antiquity of which it atteſts.

2. *Iron.*

614. Iron is a metal of a dull grey colour, but brilliant on its fracture, where it may be ſeen that it is compoſed of laminæ. It is the hardeſt (791) and the moſt elaſtic (794) of all the metals. It is the moſt ductile of the imperfect metals (789) for it may be drawn out into wire, which in fineneſs and tenacity is inferior to that of no other metal (793). If we except platina (596) iron is the moſt difficult to be fuſed of all the metals (790); but it becomes

becomes ſoft in the fire, and may be forged into any form at pleaſure: it is leſs fixed in the fire (788) than copper (602) but it is almoſt as ſonorous (795) as ſilver (588). Iron is the only body ſuſceptible of being attracted by the magnet, and it is alſo the only one capable of attracting it.

615. Iron is diſperſed everywhere throughout the earth, and is contained both in vegetables and animals. It is ſometimes found in a native ſtate; but this is rare, as it is for the moſt part mineralized with other ſubſtances. The ores in which iron approaches neareſt to the native ſtate, are in all probability thoſe ſuſceptible of being attracted by the magnet.

616. The *magnet* ought to be claſſed among the iron ores, of which it is a ſpecies, becauſe it always contains a certain quantity of this metal. Reſpecting the nature of the ſubſtance, however, united with the iron, to render it a magnet, we are utterly unacquainted. The ſpecific gravity of the magnets brought from India is 42437.

617. When iron ore is fuſed in the large furnaces, it is made to flow into a kind of mould formed in ſand. This firſt product, which is exceedingly brittle, and not at all malleable, is called *Caſt-Iron.* In this ſtate, by pouring it into different kinds of moulds, it is formed into ſtoves, pots,

pipes, and other articles, which could not be made of forged iron but at a very great expence (621).

618. To render caſt-iron malleable, it is fuſed and kneaded in a crucible; it is then put under ſtampers to free it from foreign ſubſtances; after which it is forged into ſquare or flat bars: this is what is called *Forged Iron*; the ſpecific gravity of which is 77880, while that of *caſt-iron* is only 72070 (796).

619. Iron is ſuſceptible of being reduced to a third ſtate, which is that of *ſteel*. It is converted into ſteel by expoſing it to heat in contact with carbonaceous ſubſtances, which unite themſelves with it. Here then we have three ſtates in which iron may exiſt; viz. *caſt-iron*, *forged iron*, and *ſteel*.

620. *Caſt-iron* contains too great a quantity of carbonaceous ſubſtances: it is ſteel too much ſteelified; it is therefore exceedingly brittle, and not at all malleable.

621. *Forged iron* is iron purified from all foreign ſubſtances: it is exceedingly malleable, eſpecially when hot; and in that ſtate it may be made to aſſume any form whatever.

622. *Steel* is forged iron combined, by means of cementation, with that quantity of carbonaceous

matter neceſſary for the purpoſes to which it is deſtined. It holds a mean rank between caſt-iron and forged iron. Steel in this ſtate is compoſed of ſmall grains; and when hot, poſſeſſes a conſiderable degree of malleability. It is denſer than forged iron, becauſe it has been penetrated by the carbonaceous matter. Its ſpecific gravity is 78331; but it is not harder than forged iron. To communicate to it the neceſſary hardneſs, it muſt be tempered, that is to ſay, after being expoſed to a greater or leſs degree of heat, according to the required degree of hardneſs, it is ſuddenly cooled, by immerſing it in cold water. Tempering renders it harder, more elaſtic, and more brittle: it diminiſhes a little its ſpecific gravity, for it increaſes its volume. Its ſpecific gravity after being tempered, is only 78163. Tempering alſo gives it a coarſer grain, for the mixture and penetration are leſs. On this account, each grain is more difficult to be detached from the neighbouring ones, becauſe being larger they touch each other in more points; each grain alſo is more difficult to be cut, becauſe it is compoſed of parts more analogous; and this is the cauſe which renders ſteel harder, but the connection of the whole being leſs, ſince the mixture, after being tempered, is not ſo perfect, this renders ſteel more brittle.

623. All the acids exerciſe an action more or leſs ſtriking on iron. The nitric acid is rapidly decompoſed on iron: a portion of the oxygen, by which

it was acidified, oxidates the iron, which then diſſolves, and the remainder paſſes off in nitrous gas. The ſolution is of a reddiſh brown colour. It is by this proceſs that nitrous gas is extracted (191).

624. The ſulphuric acid, if diluted with water, produces, when poured over iron, a very ſtrong effervеſcence. The water is decompoſed (267 *et ſeq.*) and its oxygen oxidates the iron, while its hydrogen paſſes off under the gaſeous form; the acid then diſſolves the oxidated iron without loſing any thing, and without changing its nature. It is by this proceſs that hydrogen gas is extracted (287).

625. Muriatic acid diluted with water, exerciſes a ſtrong action on iron. The water is decompoſed; its oxygen oxidates the metal, which the acid then diſſolves without loſing any thing; and its hydrogen paſſes off under the gaſeous form.

626. The acetous acid diſſolves iron with facility.

627. The pruſſic acid diſſolves iron, and forms *Pruſſiate of Iron*, or *Pruſſian Blue.*

628. The action of the air and of water on forged iron (681) produces a *martial oxide,* known under the name of *Aperient Crocus Martis:* it is real *carbonate of iron.*

629. If iron-filings be put into water, and if the water be agitated, you will obtain a black powder, which is an oxide of iron, known under the name of *Emery's Martial Ethiops.*

630. A mixture of ſteel-filings and ſulphur, moiſtened with water, becomes hot in the courſe of a few hours: the water is decompoſed: its oxygen produces ruſt on the iron, and converts the ſulphur into an acid, while its hydrogen eſcapes under the form of gas. The heat ſometimes becomes ſo violent as to inflame the mixture. This is what is called *Emery's Volcano.*

631. Iron may be alloyed with ſeveral metallic ſubſtances; but the only alloy of it uſed in the arts, is that with tin (633) which forms *tin-plate.*

632. The uſe of iron and ſteel in commerce is ſo extenſive and common, that nothing farther needs be ſaid on the ſubject.

3. *Tin.*

633. *Tin* is of a colour approaching near to that of ſilver (588) but ſomewhat duller. Next to lead (693) it is the ſofteſt (791) and the leaſt elaſtic (794) of all the metals: in tenacity it is ſuperior only to lead (793); though not very ductile (789)

(789) it is ſuſceptible of being reduced to very thin leaves. It is leſs ſonorous than copper, ſilver, and iron (795): except caſt-iron (678) it is the lighteſt of all the metals. Its ſpecific gravity is 72914. It fuſes with leſs heat than any of the other metals (790) and a long time before it becomes red. It may be eaſily bent, and in that caſe emits a kind of creaking noiſe: it is the only metal which poſſeſſes this property.

634. Some chemiſts aſſert that tin is ſometimes found in a native ſtate; but this is exceedingly rare: it is for the moſt part mineralized with iron, and ſometimes with ſulphur. Its ore is red, black, or white.

635. When tin has been kept for ſome time in a ſtate of fuſion, and is then expoſed to the action of the air, its ſurface becomes wrinkled, and covered with a grey pellicle, which is an *oxide of tin*. If this firſt ſtratum be removed, the tin appears below in full brilliancy; but it ſoon loſes its ſplendor, and is again oxidated. By continuing to expoſe it to heat, you may at length oxidate the whole of it. This oxide, which is *putty of tin*, is called by the tinkers *Droſs of Tin*. They take great care to remove frequently this grey pellicle, in order, as they ſay, to purify the metal; but this is only a deception, in order that they may purloin ſome of it, for they know very well how to fuſe this pretended droſs through

through charcoal, and to extract from it good tin.

636. The nitric acid ſpeedily oxidates tin by corroding it, and the metal is precipitated under the form of a white oxide. By this proceſs a great deal of nitrous gas is diſengaged. This white oxide is employed for rendering glaſs opake; and is the means made uſe of to form white enamel.

637. The ſulphuric acid, with the aſſiſtance of heat, diſſolves tin; and a part of the acid eſcapes under the form of ſulphurous acid gas (241): this acid however diſſolves tin much better when it has been already oxidated. The metal, when thus oxidated, may be precipitated by water.

638. The muriatic acid, either cold or warm, diſſolves tin, and, during the efferveſcence, a gas highly fœtid is diſengaged. The ſolution is yellowiſh, and furniſhes by evaporation cryſtals in needles, which attract the humidity of the atmoſphere.

639. The nitro-muriatic acid, and the oxygenated muriate, which may be conſidered as the ſame ſolvent, diſſolve tin very ſpeedily, and a ſtrong heat is excited. The beſt proportion for making a good ſolvent of tin is, two parts of nitric acid and one part of muriatic acid.

640. The tin uſed in commerce is alloyed with various metals: ſometimes it is mixed with a little copper (602) and biſmuth (670). The copper gives it hardneſs; the biſmuth reſtores its brilliancy, deſtroyed by the copper, and renders it more ſonorous. Pewterers ſometimes mix with it antimony (700) zinc (692) and lead (643); but in this they are wrong, and deſerve reprehenſion; antimony indeed hardens tin, and zinc whitens it; but lead makes it of a worſe quality; and the pewterers very often employ a pretty ample doſe. The preſence of lead may be detected in it by nitric acid, which diſſolves the lead, and only corrodes the tin.

641. Tin is employed in the ſilvering of mirrors, and for tinning kitchen-utenſils; but when applied to the latter purpoſe, it ought to be pure.

The braziers often add lead to it, which renders veſſels tinned with it doubly dangerous, on account of the copper (612) as well as of the tinning. They cannot employ lead however in tinning utenſils of iron, as this alloy has not ſufficient adheſion: to make the tin adhere properly, it is neceſſary that it ſhould be pure. It is very aſtoniſhing that copper-utenſils are not entirely baniſhed, and iron ones ſubſtituted in their ſtead, as iron is neither dangerous of itſelf, nor on account of its tinning.

642. Tin, when alloyed with copper, forms bronze (610); it enters alſo into the compoſition of the amalgams uſed for electric machines.

4. *Lead.*

4. *Lead.*

643. *Lead* has a duller colour than tin (633) and ſomewhat inclining to greyiſh-blue: this colour ſoon becomes tarniſhed in the air. Tin is the leaſt ductile of all the metals (789); it is alſo the ſofteſt (791) the leaſt elaſtic (794) and the leaſt ſonorous (795)); it has, likewiſe, the leaſt tenacity (793). Next to tin, it has the leaſt fixity in the fire (788); and it fuſes with a very low degree of heat, and a long time before it becomes red (790). It is the heavieſt of all the metals, gold and platina excepted (796).

644. Some authors aſſert that lead is ſometimes found in a native ſtate; but for the moſt part it is mineralized with ſulphur. This kind of ore is known under the name of *Galena*: it generally cryſtallizes in cubes: the only mines worked are thoſe of this kind: they almoſt always contain ſilver.

645. Lead ore is of different colours: ſome kinds are black, others white, and ſome green or red; the laſt kind, which is found in Siberia, is mixed with a peculiar ſemi-metal diſcovered by Vauquelin; and to which he has given the name of *Chrome* (759).

646. When

646. When lead has been kept ſome time in a ſtate of fuſion, it becomes covered with a grey oxide. This oxide, when expoſed to a ſtrong heat, aſſumes a yellow colour, and is then called *Maſſicot*: this yellow oxide may be converted into a red oxide, called *Minium*, by calcining it in a furnace after it has been reduced to a very fine powder, and waſhed in water. Theſe oxides, which eaſily become vitrified, are employed in the glaſs manufactories in the compoſition of flint-glaſs. *Litharge* alſo is an oxide of lead: there are two kinds of it, yellow and white.

647. Concentrated nitric acid converts lead into a white oxide.

648. Sulphuric acid in a ſtate of ebullition, oxidates, by means of a portion of its oxygen, a conſiderable part of the lead expoſed to its action: another part of the lead is diſſolved, and forms *ſulphate of lead*. The reſiduum is ſulphurous acid.

649. Muriatic acid poured over lead, when aſſiſted by heat, oxidates one part of it, and diſſolves another.

The ſame acid inſtantly decompoſes litharge, and excites a very ſtrong heat. The reſult is octaedral cryſtals of a dull white colour, exceedingly ponderous, and having a ſtyptic ſavour.

The affinity of muriatic acid for the *oxides of lead* is ſo great, that the latter decompoſe all the combinations of this acid. They decompoſe the muriate of ſoda, the muriate of ammonia, &c. and form *muriates of lead.*

650. The acetous acid corrodes lead, and the reſult is a white oxide, known under the name of *White Lead.* This oxide is capable of rendering white horſe-hair black; and for this reaſon it is employed by horſe-dealers to blacken thoſe parts of black horſes, which have become white, in places where they have been hurt.

Ceruſe is nothing elſe than white lead altered by a mixture of chalk (456).

651. All the oxides of lead are ſoluble in vinegar, and form *acetite of lead,* known under the name of *Salt* or *Sugar of Lead.*

652. Lead is applied to a great variety of uſes in the arts: it is employed for making water-pipes, for lining boxes, for covering houſes, and for muſket-bullets and ſmall ſhot.

653. Braziers are ſo unprincipled as to mix it with the metal employed for tinning utenſils of copper. This practice is highly dangerous (641) and deſerves puniſhment.

654. *Litharge* (646) is employed ſometimes to ſweeten ſour wine: wine-merchants who apply it to this purpoſe, deſerve the gallows, for they are poiſoners of mankind.

655. White-lead and ceruſe (650) are employed in painting; but the workmen who grind theſe colours, are ſoon or late affected with a diſeaſe, known under the name of the *Plumber's* or *Painter's Colic.*

ORDER II.

The Semi-Metals.

656. The name of *ſemi-metals* is given to thoſe metallic ſubſtances which have very little or no ductility, and which are not fixed in the fire. Like the metals, they are exceedingly heavy, and they fuſe when expoſed to heat. They then acquire ſplendor, become hard on cooling, and aſſume a convex ſurface: but what chiefly diſtinguiſhes them from the metals is, that they are very little or not at all malleable; and the greater part of them are ſublimated, or reduced to vapour when expoſed to the action of heat.

657. There are thirteen ſemi-metals known, viz. *mercury*, *biſmuth*, *cobalt*, *nickel*, *zinc*, *antimony*, *arſenic*, *mangancſe*, *tungſten*, *molybdena*, *titanium*, *chrome*, and *tellurium*.

1. *Mercury.*

658. *Mercury* differs from all the other metallic ſubſtances, by its being always in a fluid ſtate at the common temperature, and its dividing itſelf on the leaſt agitation into an indefinite number of particles, which always aſſume a ſpherical form. It retains its fluidity even in a temperature which to us would be exceedingly cold, and in which it would be impoſſible for us to live, as it never becomes ſolid but at a degree of cold equal to about 40° below zero of Fahrenheit's thermometer, or 72° below the freezing point.

659. Mercury is opake and of a bright colour, like that of poliſhed ſilver. When expoſed to the action of heat, it neither becomes calcined nor vitrified; for though it aſſumes a blackiſh colour by the action of a moderate heat, and becomes reddiſh by a ſtronger degree, and though, in diſtillation, it appears under the form of vapour or whitiſh fumes, you may very eaſily, by means of fire and without any addition, reſtore its original form and ſilvery colour. Some authors therefore have aſſerted, that it ought to be claſſed among the perfect metals (579). Next to platina (596) and gold (580) mercury is the heavieſt of all the metals (796).

660. Mercury is often found in a native ſtate in the bowels of the earth, and is then called *Virgin Mercury*. It is found in this ſtate in almoſt all the mines which produce it.

661. Sometimes it is found as a ſolid oxide, of a reddiſh brown colour, which may be reduced and brought to the ſtate of liquid mercury by heat alone. When reduced in this manner, it furniſhes oxygen gas. In general, however, it is mineralized with ſulphur; in this ſtate, if it be of a black colour, it is called *ethiops*, and if of a red colour, *cinnabar*. Both of theſe may be made artificially, by combining mercury with ſulphur. When the cinnabar is of a bright red colour, it is called *Vermilion*.—The moſt celebrated mines of cinnabar in Europe are thoſe in the Palatinate, and thoſe of Almaden in Spain.

662. Mercury is volatilized by a moderate heat: if expoſed to a ſtronger degree, it boils like liquids, becauſe, like them, it is reduced into vapour in the places moſt expoſed to the fire; whereas other metals are never reduced to vapour but at their upper ſurface.

663. Mercury, though repeatedly diſtilled, experiences no alteration; a little of it only is converted into a grey powder, which becomes liquid on being merely pounded. By the action of the air, and a

heat

heat capable of making it boil, mercury gradually loſes its fluidity, and at the end of ſome months forms a red oxide: this is what is called *Mercury precipitated per ſe.* This oxide is revived merely by heat, and furniſhes a great deal of oxygen gas. Two pounds, 399·15 grains of mercury, thus oxidated, can furniſh of this gas about 3012·984 cubic inches *.

664. The nitric acid diſſolves mercury with violence, and ſuffers to eſcape a large quantity of nitrous gas. The reſiduum is *nitrate of mercury*, which is corroſive. If this nitrate be heated in a crucible it fuſes, ſtill gives out a great deal of nitrous gas, and loſes its water of cryſtallization: the oxide which remains, firſt becomes yellow, then acquires a bright red colour, and forms what is called *Red Precipitate of Mercury*.

665. The ſulphuric acid has no action on mercury, unleſs aſſiſted by heat; ſulphurous acid gas is then diſengaged, and a white oxide is precipitated. If warm water be poured over this oxide, it becomes yellow; and is known under the name of *Yellow Oxide*, or *Turbith Mineral*.

666. Though the muriatic acid has no ſenſible action on mercury, yet, if digeſted for a long time

---

* Or a chiliogramme can furniſh 59 cubic litres, 766679 cubic millimetres, which is nearly 60 litres.

over this metal, it becomes oxidated; and the reſult is a *muriate of mercury*. If this muriate be little charged with oxygen, it forms what is called *Sweet Mercury*; but if ſaturated with oxygen, the reſult is corroſive muriate of mercury, known under the name of *Corroſive Sublimate*, which is ſoluble in water; whereas ſweet mercury is inſoluble in that liquid. This furniſhes a ſimple method of ſeparating them when mixed.

667. To obtain mercury perfectly pure, it muſt be revived from cinnabar (661): for this purpoſe, three parts of cinnabar and two parts of iron-filings are diſtilled together: the mercury paſſes over very pure, and is known under the name of *Mercury Revived from Cinnabar*.

668. Mercury may be united by amalgamation to different metals. On this property is founded the arts of gilding metals, of ſilvering mirrors, of extracting gold and ſilver from their ores, &c.

669. Mercury is employed with advantage for meteorological inſtruments: 1ſt, It freezes with great difficulty; 2d, It expands in a pretty uniform manner; 3d, It may be obtained always of an equal quality, by employing that which has been revived from cinnabar.

2. *Biſmuth.*

670. *Biſmuth* is of a yellowiſh white colour: it is brittle, and readily breaks under the hammer. Next to mercury (659) it is the heavieſt of all the ſemi-metals (796) and the eaſieſt to be fuſed (790); it enters into fuſion long before it becomes red, and with a moderate degree of heat; while fuſing it emits fumes, but it does not become volatilized.

671. Biſmuth is found native, or mineralized by ſulphur, or by arſenic (707). Native biſmuth is ſometimes cryſtallized in cubes: it is found alſo in tuberous maſſes like ſtalactites (458).

672. Biſmuth, when brought to a red heat, burns with a faint blue flame, and emits yellowiſh fumes; which, when condenſed, form what are called *Flowers of Biſmuth.*

673. The nitric acid ſpeedily oxidates biſmuth, and nitrous gas is diſengaged: a portion of the oxide afterwards diſſolves, and forms a *nitrate of biſmuth.*

674. Sulphuric acid boiled over biſmuth, diſſolves it in part, ſuffering ſulphurous acid gas to eſcape; and the reſult is a ſulphate of biſmuth exceedingly deliqueſcent.

675. The muriatic acid has but a ſlow action on biſmuth, even when very much concentrated; the reſult is a *muriate of biſmuth*, which ſtrongly attracts the moiſture of the atmoſphere.

676. Water precipitates biſmuth from all its ſolutions: the reaſon of this no doubt is, that the acids, being thus weakened by the water, are no longer able to hold the biſmuth in ſolution: this precipitate, when well waſhed, is known under the name of *Magiſtery of Biſmuth*, or *White Paint*. The ladies who make uſe of it are very imprudent, for, beſides the danger of this practice, their complexion ſoon becomes of a leaden colour; and their ſkin, by theſe means, is rendered blacker than it was before.

677. Biſmuth may be alloyed with all the metals; but it is difficult to unite it by fuſion to the ſemi-metals.

678. Biſmuth forms an amalgam with mercury (658) and renders it leſs fluid. On account of this property, it might be employed with advantage in the ſilvering of mirrors, by adding a little of it to the mercury and tin uſed for that purpoſe.

3. *Cobalt.*

3. *Cobalt.*

679. *Cobalt* is of a pale or grey colour, inclining to red: it is hard (792) but fuſible, and almoſt of an earthy nature. In the fire it has a conſiderable degree of fixity, and does not inflame or emit fumes: it fuſes (790) but requires almoſt as ſtrong a degree of heat as that neceſſary to fuſe iron. Next to mercury and biſmuth, it is the heavieſt of the ſemi-metals.

680. Cobalt in its ores is combined with ſulphur, arſenic, and ſome other metallic ſubſtances.

681. Oxide of cobalt, when freed from arſenic, is known under the name of *Zaffer.* Zaffer, when fuſed with three parts of quartz (547) and one part of potaſh, forms *ſmalt*, which is a kind of glaſs, of a beautiful blue colour: this glaſs pulverized, forms the *blue* employed for colouring ſtarch: it is uſed alſo by the painters of earthen-ware, porcelain, &c. and to colour different kinds of glaſs blue.

682. Cobalt is ſoluble in acids. The nitric acid diſſolves it with effervеſcence; and the reſult is cryſtals in needles, which decrepitate and fuſe on the coals.

683. The ſulphuric acid diſſolves cobalt, and ſuffers ſulphurous acid gas to eſcape; the reſult is *ſulphate of cobalt*, which is ſoluble in water. Lime (404) magneſia (411) barytes (416) and alkalies (840) decompoſe this ſulphate, and precipitate the cobalt in an oxide; which, by its oxidation, is increaſed four-tenths in weight (798).

684. The muriatic acid does not diſſolve cobalt cold; but, by the aid of heat, it diſſolves a portion of it. This acid has a more powerful action on zaffer (681) and the ſolution is of a beautiful green colour.

685. The nitro-muriatic acid alſo diſſolves cobalt, and forms a ſympathetic ink, called by Hellott, *Ink of Biſmuth.*

686. Ammonia diſſolves zaffer; and the reſult is a liquor of a beautiful red colour.

4. *Nickel.*

687 *Nickel* is a ſemi-metal, diſcovered not long ago by Cronſted, a Swediſh mineralogiſt. It is of a whitiſh red colour: it is always mixed with arſenic (707) and iron (614); from the latter of which it can, only with great difficulty, be entirely freed. Its ſpecific gravity is nearly equal to that of cobalt (796).

688. That kind of nickel-ore, known under the name of *Kupfer-nickel*, is of a reddiſh yellow colour. It is found in different parts of Germany, as well as in Dauphiny and the Pyrenees.

689. The nitric acid attacks oxide of nickel, as well as nickel itſelf, with great vivacity: this ſolution produces cryſtals, in rhomboidal cubes, of a beautiful emerald-green colour.

690. The ſulphuric acid, diſtilled from off nickel, ſuffers ſulphurous acid gas to eſcape; and there remains a greyiſh *ſulphate of nickel*, which, when diſſolved in water, gives it a green colour.

691. The muriatic acid diſſolves nickel alſo, but only when warm: this ſolution gives cryſtals in the form of long rhomboidal octaedra, and of a moſt beautiful emerald-green colour.

5. *Zinc.*

692. *Zinc* is of a bluiſh white colour, and poſſeſſes conſiderable brilliancy. Of all the ſemi-metals it is the leaſt brittle; and, on that account, it is exceedingly difficult to reduce it to powder: it even has a certain degree of ductility (789) and may almoſt be worked under the hammer: it is ſuſceptible alſo of being rolled into very thin leaves.

In that ſtate it burns in the flame of a taper, and gives it a blue colour mixed with green. Zinc, when expoſed to heat, ſoon enters into fuſion (790) and long before it becomes red; the degree of heat which it requires for this purpoſe being only a very little higher than that neceſſary to fuſe lead (643). Its ſpecific gravity (796) is ſomewhat leſs than that of caſt-iron (617).

693. When zinc is brought to a red heat, it burns with a blue flame, and throws out white flakes, called *Flowers of Zinc.* If water be poured over zinc when it begins to be red, the former will be decompoſed. Its oxygen (275 and 276) oxidates the zinc, and a great deal of hydrogen gas is diſengaged.

694. Zinc, in general, is mineralized with ſulphur; and this ore is known under the name of *Blende:* very often it contains iron. When blende is decompoſed the reſult is *ſulphate of zinc.*

695. Zinc is found alſo in the ſtate of oxide. If the ſulphur is diſſipated without producing a ſulphate, its place is occupied by oxygen; and the reſult is that oxide of zinc, known under the name of *Calamine,* which is almoſt always mixed with iron. This ore is the only kind worked, in order to extract zinc from it.

696. The nitric acid, even when diluted with water, diſſolves zinc with violence, and forms a *nitrate of zinc* exceedingly deliqueſcent.

697. The ſulphuric acid diſſolves zinc cold; and it is probable that in this caſe water is decompoſed, for a great deal of hydrogen gas eſcapes. By evaporation you may then obtain a ſalt, known under the name of *Sulphate of Zinc*, or *White Vitriol.*

698. The muriatic acid diſſolves zinc with efferveſcence; and hydrogen gas is produced in the ſame manner as with the ſulphuric acid (697): afterwards there is a precipitation of black flakes, which are *muriate of zinc.*

699. One part of zinc alloyed with three parts of copper, forms that metal called *Braſs* (611).

6. *Antimony.*

700. *Antimony* is of a whitiſh colour: it is ſo brittle that it readily breaks under the hammer: its interior texture appears to be ſtriated and compoſed of filaments. It volatilizes entirely in the fire, and communicates the ſame property to metals with which it is mixed. It fuſes at a degree of heat ſomewhat higher than that neceſſary to fuſe zinc (790); and, when in fuſion, ſuffers to eſcape white fumes,

fumes, known under the name of *Flowers of Antimony*. When calcined it is ſuſceptible of vitrification: the glaſs it produces is of a reddiſh brown, or hyacinth-colour (527). This glaſs, ground on porphyry, and boiled with two parts of the acidulous tartrite of potaſh, forms *antimoniated tartrite of potaſh*, known under the name of *Stibiated Tartar*, which is an excellent emetic. Antimony is a little heavier than arſenic (707) molybdena (733) tellurium (769) and tungſten (727); but is inferior in weight to all the other ſemi-metals (796).

701. Antimony is generally mineralized with ſulphur. Sometimes it is found combined with arſenic (707): this laſt ore is as white as ſilver (588).

702. Antimony is employed in commerce in two ſtates: 1ſt, Under the form of *crude antimony*, which is nothing elſe than ſulphurous antimony freed from its matrix: 2d, Under the form of *regulus of antimony*, which is antimony deprived of its ſulphur. The metallic button, in this caſe, exhibits at its ſurface a kind of ſtar compoſed of diverging rays.

703. The nitric acid eaſily decompoſes antimony; it oxidates a great part of it, and diſſolves a portion, which is capable of forming a very deliqueſcent ſalt. The oxide, which is white, is that ſubſtance called *Bezoar Mineral*. If equal parts of

ſulphuret

ſulphuret of antimony and nitrate of antimony be made to detonate in a crucible brought to a red heat, you will obtain *ſulphurized oxide of antimony*, called *Liver of Antimony.* This oxide, when pounded and waſhed, is what is called *Crocus Metallorum:* when it aſſumes a yellow colour it is called *Golden Sulphur of Antimony:* if it has a red colour, it is diſtinguiſhed by the name of *Kermes Mineral:* if of a brown colour, it is called *Ruby of Antimony.*

704. If four parts of ſulphuric acid be boiled over one part of antimony, the acid, by oxidating the metal, is in part decompoſed. At firſt, ſulphurous acid gas eſcapes, and towards the end of the proceſs, ſulphur is ſublimated in a natural ſtate: the reſiduum is *oxide of antimony.*

705. The muriatic acid has no action on antimony but when digeſted over it for a long time. The *muriate of antimony* thence obtained, is exceedingly deliqueſcent.

706. Wine and the acetous acid diſſolve antimony, and, by theſe means, become emetic; but emetic wine is a hazardous remedy, becauſe we are not acquainted with its degree of energy, as it depends on the acidity of the wine employed: a property too variable. It is prudent, therefore, to make no uſe of this remedy.

7. *Arſenic.*

707. *Arſenic*, in the metallic ſtate, is of a blackiſh grey colour. It is brittle, and its fracture has a conſiderable reſemblance to that of ſteel (622); but it readily tarniſhes. It is the lighteſt of all the metals and ſemi-metals (796). If arſenic be thrown into a crucible brought to a bright red heat, it burns with a blue flame, and is volatilized into a white oxide, which has a ſtrong ſmell of garlic.

708. Arſenic, when alone, fuſes with difficulty; yet it may be alloyed by fuſion with moſt of the metals: it whitens thoſe which have a colour inclining to yellow or red, gives brittleneſs to thoſe which are ductile, renders thoſe which fuſe alone with difficulty more fuſible, and makes thoſe which are fuſible refractory.

709. Arſenic is found ſometimes in a native ſtate, but for the moſt part is combined in its ore with different metals: theſe metals are diſengaged from it by calcination. During this proceſs, the arſenic is exhaled under the form of white fumes; which, being condenſed, attach themſelves to the ſides of the chimney, and form an *oxide of arſenic*, that may be afterwards detached and collected. This is the arſenic ſold in commerce: it is of a ſhining

white

white colour, and either opake or tranſparent. It fuſes by heat, and is volatilized in a white ſmoke, which emits an odour of garlic, exceedingly dangerous. This oxide is perfectly ſoluble in water.

710. Oxide of arſenic is ſuſceptible of combining with ſulphur, and the reſult is either *orpiment* or *realgar*, which differ from each other only in conſequence of the degree of heat they have experienced; for if orpiment be expoſed to a ſtrong heat, it may be converted into realgar, and it then aſſumes a colour inclining to red; whereas orpiment is only yellow.

711. The nitric acid, aſſiſted by heat, diſſolves oxide of arſenic, and forms a deliqueſcent ſalt.

712. Sulphuric acid in a ſtate of ebullition diſſolves oxide of arſenic; but the oxide is precipitated by cooling.

713. The muriatic acid, whether cold or warm, has only a very weak action on arſenic.

714. When a very large quantity of oxygen is combined with arſenic, ſo that it becomes ſaturated, it forms an acid called the *Arſenic Acid*. To obtain this acid, either oxygenated muriate or nitric acid is diſtilled from off oxide of arſenic. The oxygenated muriate gives up its exceſs of oxygen

to

to the oxide of arſenic, and returns to the ſtate of muriatic acid; the nitric acid, in the like manner, reſigns a portion of its oxygen to the oxide, and eſcapes in the form of nitrous gas: in both theſe caſes the oxide of arſenic is acidified. The *arſenic acid* is much more ſoluble in water than the *oxide of arſenic*; for three parts of the former diſſolve in two parts of water at the temperature of fifty-nine degrees; while, at the ſame temperature, eighty parts of water are neceſſary to diſſolve one part of the oxide.

715. The oxide of arſenic is exceedingly dangerous: on the firſt view it may be miſtaken for ſugar. If there be any cauſe of ſuſpicion, it may be eaſily detected by throwing it into the fire; the white ſmoke and ſmell of garlic which it emits will prove it to be arſenic.

8. *Manganeſe.*

716. *Manganeſe* was diſcovered in 1764 by Bergmann, who aſſerted that the manganeſe, conſidered as iron or cobalt ore, muſt contain a peculiar metal. Gahn, a Swediſh phyſician, by the aſſiſtance of a very violent heat, found means to extract from it a metallic ſubſtance of a white colour, inclining to grey, different from thoſe before known, and which was claſſed among the ſemi-metals, under the name of *Manganeſe*.

717. Manganeſe is the hardeſt of all the ſemimetals (792): when alone, it is more difficult to be fuſed than iron (790); but it readily fuſes with the other metallic ſubſtances, except pure mercury. It has leſs ſpecific gravity than zinc; but more than antimony (796).

718. Manganeſe is always found in the earth in the ſtate of oxide: this oxide is ſometimes grey, brilliant, and cryſtallized in very ſmall priſms; at other times it is of a reddiſh white colour; but, for the moſt part, it is black, friable, exceedingly light, and ſtains the fingers: this kind is the beſt. When expoſed to heat in cloſe veſſels, it furniſhes a conſiderable quantity of oxygen gas: four ounces of oxide can furniſh eight or nine pints.

719. Manganeſe, when expoſed to a very violent heat, vitrifies and forms glaſs of an obſcure yellow colour. If expoſed to the air, it becomes oxidated into a brown powder, and its weight is augmented $\frac{68}{100}$ (798).

720. Almoſt all the acids have a ſtronger or weaker action on manganeſe and its oxides. The nitric acid diſſolves it with efferveſcence, and forms a *nitrate of manganeſe*. The oxides of manganeſe are ſoluble in nitric acid; but this acid does not then loſe its oxygen, becauſe it finds the metal already oxidated.

721. The

721. The ſulphuric acid attacks mangaueſe, and there is diſengaged hydrogen gas, ariſing from a portion of the water decompoſed, the oxygen of which has oxidated the metal. Manganeſe diſſolves more ſlowly than iron (624); but if ſulphuric acid be poured over oxide of manganeſe, and if its action be aſſiſted by a gentle heat, a large quantity of oxygen gas is diſengaged, and there remains a white powder ſoluble in water; which, by evaporation, furniſhes *ſulphate of manganeſe.*

722. The muriatic acid diſſolves manganeſe, and forms with it a *muriate*; but if it be digeſted over the oxide, it ſeizes on its oxygen, and eſcapes in the form of oxygenated muriatic gas (201) which is employed for bleaching linen cloth, cotton, &c.

723. Fluoric acid diſſolves manganeſe only in a ſmall quantity, and forms with it a ſalt not very ſoluble; but if the nitrate, ſulphate, or muriate of manganeſe be decompoſed by fluate of ammonia, *fluate of manganeſe* is precipitated.

724. The acetous acid has only a weak action on manganeſe; but if the acid be digeſted over oxide of manganeſe, it acquires the property of diſſolving copper (602) while the ſame acid digeſted over copper only corrodes it, and forms verdigriſe (608).

725. Manganeſe is precipitated from its ſolutions by alkalies, in the form of a whitiſh gelatinous ſubſtance,

ſtance, which grows black by being in contact with the air. Chaptal aſcribes this black colour to its abſorbing oxygen gas f om the air; for having ſhaken the precipitate in bottles filled with oxygen gas, the black colour was produced in one or two minutes, and a conſiderable part of the gas was abſorbed.

726. Oxide of mangaheſe is employed in glaſs-houſes, to free glaſs from its green or yellow tint; and, for this reaſon, it has been called *Glaſs-maker's Soap*. It is employed alſo for giving a violet colour to glaſs and porcelain.

9. *Tungſten.*

727. *Tungſten*, or rather its ore, is of a ſteel-grey colour. It is exceedingly hard (792) as well as brittle, and cryſtallizes in octaedra. When alone it is more infuſible (790) than mangaheſe (717); it decrepitates in the fire, and does not melt. The ſpecific gravity of this ore is 60665; that of its regulus is 66785.

728. Tungſten fuſes with ſoda, with a little effervеſcence; but with borax without effervеſcence.

729. If nitric acid be poured over pulverized tungſten, the powder acquires a beautiful bright

yellow colour. Some aſſert that this is pure *tungſtic acid*, which exiſted completely formed in the metal; other chemiſts, however, conſider this powder only as an oxide of *tungſten*, which has none of the characters of an acid. The tungſtic acid is ſometimes white; but it is not thought to be ſo pure as the yellow. The white acid, when brought into contact with a plate of iron, immediately produces a beautiful blue colour.

730. *Wolfram* is a real ore of tungſten, mixed with oxides of iron and of manganeſe: it contains two-thirds of tungſten. Its ſpecific gravity is 71195.

731. Wolfram is of a blackiſh brown colour: its ſurface is often ſtriated, and its fracture exhibits a lamellated and foliaceous texture. When freed from the oxides of iron and manganeſe, it poſſeſſes all the properties of tungſten:—it is real tungſten.

732. Mineral acids poured over wolfram convert it into a yellow powder; which, as we have already ſaid (729) is tungſtic acid. It is probable that theſe acids only free the wolfram from the other ſubſtances which the tungſten contains, and which are united with it.

10. *Molybdena.*

733. The *regulus of molybdena* is compoſed of ſmall round grains, of a greyiſh colour. It is exceedingly refractory, and is as infuſible as tungſten (790). It may be alloyed with metals different ways.

734. Regulus of molybdena, when expoſed to heat, paſſes to the ſtate of an oxide more or leſs white. This regulus, when treated with three parts of ſulphur, regenerates its ore; and it is then molybdena mineralized with ſulphur. It is compoſed of ſcaly particles, not very intimately connected with each other. It is of a bluiſh colour, approaching near to that of lead (643). It is ſoft and fatter to the touch than plumbago, which is a ſort of iron ore: it ſtains the fingers, and leaves on paper traces of an aſh-grey colour, with the brilliancy of ſilver.

735. Ore of molybdena can be attacked with efficacy only by the nitric and arſenic acids; but it fuſes with ſoda with effervefcence. According to Kirwan, 100 parts of this ore contain 45 of the regulus of molybdena, and 55 of ſulphur. Its ſpecific gravity is 47385. If this ore be calcined, the reſiduum is a whitiſh earth, which is *oxide of molybdena:* when expoſed to the blow-pipe, it emits

white fumes, which are probably its acid, for this ſemi-metal is acidifiable (832).

736. To obtain *molybdic acid*, thirty parts of nitric acid muſt be diſtilled over one part of pounded molybdena. A great deal of nitrous gas eſcapes (191) and there remains a reſiduum, white as chalk, which is molybdena combined with the oxygen of the nitric acid. This is molybdic acid.

737. Arſenic acid, diſtilled from off ore of molybdena, produces alſo molybdic acid; which is always formed by the combination of the oxygen of the acid employed with the regulus of molybdena. According to Bergmann, the ſpecific gravity of this acid is 34600.

738. Concentrated ſulphuric acid diſſolves a large quantity of molybdic acid: the ſolution is of a beautiful blue colour, which diſappears by heat, and reappears when the liquor cools.

739. Muriatic acid alſo, by the help of ebullition, diſſolves a great deal of molybdic acid. If this ſolution be diſtilled, you will obtain a reſiduum of a dark blue colour; and if this reſiduum be expoſed to a ſtronger heat, it produces a white ſublimate mixed with blue. This ſublimate is molybdic acid, volatilized by muriatic acid.

11. *Tita-*

11. *Titanium.*

740. We are as yet very little acquainted with the nature or properties of this mineral. Klaproth, a chemiſt of Berlin, firſt diſcovered that a ſubſtance found at Boinik, in Hungary, known under the name of *Red Schorl*, was an oxide of a new metallic ſubſtance, diſtinct from all the others; and to which he gave the name of *Titanium*. This ſubſtance is found in ſeveral other places, particularly in the biſhopric of Paſſau, in Germany, where it is united with lime and ſilex, in the proportion of about a third of each; in Bavaria, where it is united to iron and mangaueſe, but only a ſmall quantity of the latter; near Pont-James-les-Noyers, between Nantes and Ingrande, where the ore contains about a half of the oxide of titanium; and at St. Yrieux, about eight leagues from Limoges. It is probable that it will be found alſo in many other places.

741. We may therefore conſider the mineral, known under the name of *Red Schorl*, as an oxide of titanium. I do not know whether the regulus of it has ever yet been obtained; but Vauquelin ſays that, when analyzing the red ſchorl of France, he obſerved a metallic cruſt of a cupreous red colour, which he judged to be titanium in the metallic ſtate.

In what follows, we muſt be underſtood as ſpeaking only of the oxide of titanium.

742. *Oxide of titanium* is of a red colour, ſometimes bright and ſometimes dark: it is ſo hard as to be able to ſcratch glaſs: it is difficult to reduce it to powder: when broke, both its fractures are exceedingly brilliant, and exhibit very ſmooth ſurfaces. Its ſpecific gravity is 42469. If this oxide be expoſed to a ſtrong heat, neither its form nor its ſplendor is in the leaſt altered; its colour only becomes a little darker.

743. Oxide of titanium is abſolutely proof againſt acids until it has been heated with a cauſtic alkali; but when once heated, it becomes ſoluble.

744. Nitric acid diſſolves it completely: by ſpontaneous evaporation the ſolution acqnires the conſiſtence of oil, and ſmall diaphonous, rhomboidal cryſtals are obſerved in it.

745. The muriatic acid diſſolves it alſo. When expoſed to ſpontaneous evaporation, this ſolution becomes a tranſparent gelatinous maſs, of a bright yellow colour, and preſents ſmall cubical, diaphonous cryſtals.

746. The ſulphuric acid diſſolves it by the help of ſlight digeſtion. The ſolution, when evaporated, produces

produces a maſs which has a reſemblance to the gluten of farina.

747. The ſulphuric, nitric, muriatic, and nitro-muriatic acids, do not in any manner attack native oxide of titanium reduced to powder; but if one part of this oxide in powder, and five parts of the carbonate of potaſh, be brought to a red heat in a porcelain crucible, the mixture will ſoon enter into fuſion. This mixture, when poured on a plate of metal, forms a ſolid maſs, of a whitiſh grey colour. If it be then pounded and diluted in boiling water, it depoſits a white powder, ſoluble in the four acids above mentioned, which cannot attack the oxide: but if this white powder be heated in a crucible, and be in a manner calcined, it becomes inſoluble in theſe acids.

748. The colour of this white powder is changed by calcination; it paſſes from white to yellow, and to red; and, by the contact of charcoal, it becomes blue. It gives a yellow enamel. It is precipitated from its ſolutions in acids by pruſſiate of potaſh, by gallic acid, and by ſulphuret of ammonia. By means of tin and zinc it may be reduced, in the humid way, into flakes of a dark colour.

749. This white powder has a very great affinity for oxygen; for the oxide of titanium, in its natural ſtate, is completely ſaturated with oxygen: this, no doubt,

doubt, is what renders it inſoluble in acids, unleſs it has loſt part of its oxygen by fuſion with cauſtic alkali.

750. Oxide of titanium is precipitated from its ſolutions in white flakes, by carbonate of potaſh, and by potaſh itſelf.

751. Alkaline carbonates produce an abundant precipitate of a dark green colour, intermixed with brown.

752. Gallic acid produces a brown precipitate, inclining to red.

753. Arſenic acid (714) and phoſphoric acid give, from theſe ſolutions, a white precipitate.

754. The tartareous and oxalic acids produce a white precipitate, which is afterwards rediſſolved without leaving any reſiduum.

755. Ammonia poured into a ſolution of this oxide by muriatic acid, gives it a dirty green colour, and there is formed a bluiſh green precipitate.

756. Zinc put into the ſame ſolution, diluted with water, firſt produces a violet colour, which at laſt paſſes to an indigo-blue: this blue diſappears entirely by heat, while the oxide is completely precipitated.

757. A

757. A plate of tin immerſed in a muriatic ſolution of this oxide, if put into a bottle well ſtopped, gives the ſolution a pale roſe colour, which changes to an amethyſt-violet colour.

758. Oxide of titanium treated with borax, forms a globule of a hyacinth colour. The ſame oxide, when in a native ſtate, if fuſed with the enamel of porcelain, gives it a pure and uniform ſtraw colour*.

12. *Chrome.*

759. *Chrome* is a ſemi-metal, lately diſcovered by Vauquelin; reſpecting the nature and properties of which we are as yet little acquainted. Vauquelin gave it the name of *Chrome*, becauſe it is it which communicates the red colour to the ruby (516) and the green to the emerald (385). It was found by this chemiſt, in the ſtate of an acid, in a ſubſtance before known under the name of the *Red Lead-ore of Siberia*. The mineralizing ſubſtance of this red lead is therefore a real acid; the radical of which is a peculiar metallic body, now called *Chrome*.

760. This acid, named the *Chromic Acid*, has properties which do not belong to any other metallic acid.

---

* Journal des Mines, No. xv, p. 1, and No. xix. p. 51 and 57.

acid. It is of a ruby-red colour, and communicates to all its combinations red or yellow tints, more or leſs dark. It gives up to the muriatic acid a part of its oxygen, and converts it into oxygenated muriate, which is a good ſolvent of gold; while it itſelf paſſes to the ſtate of green oxide, ſoluble in muriatic acid. With mercury, it forms a combination of a cinnabar-red colour (661); with ſilver, a compoſition of a carmine-red colour; with lead, an orange mineral; and with hydro-ſulphuret of potaſh, a ſubſtance of an olive-green colour, &c.

761. Chromic acid has a pungent and metallic ſavour. It is exceedingly ſoluble in water, and its ſolution cryſtallizes by evaporation into ſmall long priſms, of a ruby-red colour.

762. This acid readily unites with barytes (416) and forms with it a ſalt very little ſoluble in water, of a pale lemon-yellow colour. It has no ſenſible ſavour. It may be decompoſed by the mineral acids: when expoſed to heat it furniſhes oxygen gas, after which it remains in the ſtate of a green earthy maſs.

763. This acid combines with lime (404); and the ſalt it produces does not appear to be more ſoluble than the preceding.

764. This acid, by its combination with alkalies, forms coloured ſalts, ſoluble and ſuſceptible of cryſtallization,

tallization. To prepare theſe ſalts, one part of the red lead-ore finely pounded, and two parts of alkaline carbonate, muſt be boiled in forty parts of water. The carbonic acid then forms with the lead a carbonate of lead, which is precipitated; and the chromic acid forms, with the alkali, a combination which remains diſſolved in the water; ſo that the two acids have changed baſes.

765. To obtain, in a ſtate of perfect purity, the ſalt formed by the chromic acid and the alkali, it will be neceſſary not to add too much of the alkaline carbonate, for ſome of it might be undecompoſed and mixed with this ſalt: but if ammoniacal carbonate be employed, you may add more than is requiſite for ſaturating the chromic acid, becauſe the exceſs of the ammoniacal carbonate volatilizes, and the chromic ſalt remains pure.

766. Combinations of the chromic acid with alkalies, are of a lemon colour. Theſe ſalts are decompoſed by barytes (416) lime (404) and ſtrontian (429) which have more affinity for chromic acid than alkalies have. They are decompoſed alſo by the mineral acids, but inverſely; that is to ſay, the mineral acids ſeize upon the alkalies, and the chromic acid remains free. Theſe ſalts decompoſe, by a double affinity, the calcareous, barytic, magneſian, and aluminous ſalts.

767. The chromic acid may be reduced to the metallic ſtate, by putting it into a charcoal crucible, placed within another of hard porcelain, filled with pounded charcoal, and expoſing the whole to a very ſtrong heat for an hour in a common furnace: the reſult will be a greyiſh brilliant metallic maſs, exceedingly brittle; having at its ſurface a great many feathered cryſtals of the ſame colour, and perfectly metallic. By the reduction of chromic acid into the metallic ſtate, it is found that this acid contains $\frac{4}{10}$ of oxygen; that is to ſay, that in 100 parts there are 60 of chrome and 40 of oxygen.

768. The nitric acid attacks chrome with difficulty; but, by repeated operations, the latter becomes oxidated, and even acidified. When only oxidated, it is green; but acidified, it is red. It communicates its colours to its different combinations. It is aſcertained by the analyſis of the emerald of Peru (535) that it derives its green colour from the oxide of chrome; and, it is probable that the red colour of the ruby (516) is owing to the chromic acid.*

13. *Tellurium.*

769. Klaproth, a chemiſt of Berlin, having ſubjected to chemical analyſis an auriferous ore of

---

* See the Journal des Mines, No. xxxiv, p. 737.

Tranſylvania, known under the appellation of *White Gold Ore*, found in it a metal abſolutely different from all the others, to which he gave the name of *Tellurium*. About the year 1782, Muller, of Reichenſtein, had ſuſpected that this mineral contained a peculiar metallic ſubſtance; Bergman had the ſame idea, but did not declare it in a deciſive manner. The ingenious experiments of Klaproth, however, confirmed the conjectures of both.

770. Tellurium has a white colour like that of tin, and approaching near to a leaden grey. It poſſeſſes great metallic ſplendor, and its fracture appears lamellated. It is exceedingly brittle and friable. It is among the moſt fuſible of the metals; and, when fuſed, if it be ſuffered to cool gradually and at reſt, it readily aſſumes a cryſtalline ſurface. When expoſed to the blow-pipe on a piece of charcoal, it burns with a pretty bright flame of a blue colour, which at the edges appears greeniſh. It volatilizes entirely in fumes of a whitiſh grey colour, and emits a diſagreeable odour. If you ſuſpend the heat before it is entirely volatilized, the remaining button retains its liquidity for a long time, and becomes covered, on cooling, with a radiated vegetation. The ſpecific gravity of tellurium (796) is ſomewhat greater than that of molybdena (733).

771. Tellurium diſſolves in nitric acid: the ſolution is colourleſs and tranſparent. When concentrated,

centrated, it produces, in the courſe of time, ſmall light cryſtals, in the form of needles.

772. It diſſolves alſo in the nitro-muriatic acid. When a large quantity of water is added to this ſolution, after it has been ſaturated, the tellurium is precipitated in the ſtate of oxide, under the form of a white powder, which is ſoluble in muriatic acid.

773. If a ſmall quantity of tellurium be mixed, cold, with 100 times its weight of concentrated ſulphuric acid, the acid gradually aſſumes a beautiful crimſon red colour; if a little water be added, drop by drop, the colour diſappears, and the metal, which has been diſſolved, is depoſited under the form of black flakes. Heat alſo makes the red colour diſappear, and diſpoſes the tellurium to ſeparate itſelf in the ſtate of a white oxide.

774. On the other hand, when the concentrated ſulphuric acid is diluted with two or three parts of water, if a little nitric acid be added to it, the ſulphuric acid then diſſolves a conſiderable quantity of tellurium: the ſolution is tranſparent and colourleſs, and is not decompoſed by the mixture of a larger quantity of water.

775. All the pure alkalies precipitate from acid ſolutions of tellurium a white oxide, ſoluble in all the

the acids. By an exceſs of alkali, the precipitate which has been formed is entirely re-diſſolved.

776. Very pure pruſſiate of potaſh occaſions no precipitate in acid ſolutions of tellurium.

777. The alkaline ſulphurets, mixed with acid ſolutions of tellurium, produce a precipitate of a brown or blackiſh colour, according as the metal in it is combined with more or leſs oxygen. It ſometimes happens that the colour of the precipitate has a perfect reſemblance to that of kermes mineral, or red ſulphurated oxide of antimony (703).

778. An infuſion of gall-nuts, combined with theſe ſolutions, gives birth to a flaky precipitate, of an Iſabella colour.

779. Iron and zinc precipitate tellurium from its acid ſolutions in the metallic ſtate, under the form of ſmall black flakes, which reſume their ſplendor by friction, and which fuſe on burning charcoal, and form a metallic button. Tin and antimony produce the ſame phenomenon.

780. Oxide of tellurium, obtained by alkalies from its acid ſolutions, or by acids from its alkaline ſolutions, is reduced, in either caſe, with great rapidity. When expoſed to heat on charcoal, it burns, and is volatilized.

781. If heated for ſome time in a retort, this oxide of tellurium fuſes, and re-appears, after it has cooled, of a ſtraw colour.

782. Oxide of tellurium, when mixed with fat bodies, may be completely reduced.

783. It appears by the chemical analyſis of the different kinds of gold-ore, in which tellurium is found (769) that they contain as follows:

784. A hundred parts of the white gold-ore of Fatzbay contain,

Tellurium metal	25·5
Gold — —	2·5
Iron — —	72·
	100

785. A hundred parts of the graphic gold-ore of Offenbanya contain,

Tellurium metal	60
Gold — —	30
Silver — —	10
	100

786. A hundred parts of the yellow gold-ore of Nagyag contain,

Tellurium metal	45
Gold — —	27
Silver — —	8·5
Lead — —	19·5
Sulphur one atom	
	100

787. A hundred parts of the foliated grey ore of Nagyag contain,

Tellurium metal	33
Gold — —	8·5
Silver and copper	1
Lead — —	50
Sulphur —	7·5
	100

TABLES OF THE DIFFERENT PROPERTIES OF METALLIC SUBSTANCES.

788. *Fixity of Metals in the Fire in the decreaſing Order:*

Gold
Platina
Silver
Copper
Iron
Lead
Tin.

789. *Ductility of the Metals and Semi-metals in the decreaſing Order.*

Gold
Platina
Silver
Iron
Tin
Copper
Lead
Nickel
Zinc
Tungſten
Biſmuth
Cobalt
Antimony
Manganeſe
Arſenic
Molybdena
Titanium } unknown.
Chrome
Tellurium

790. *Fuſibility of the Metals and Semi-metals in the decreaſing Order.*

The heat neceſſary for effecting the fuſion of metallic ſubſtances, which require a ſtrong degree, has been meaſured by Wedgewood's pyrometer, each degree of which is equal to 130 degrees of Fahrenheit's ſcale; therefore 130 degrees of the pyrometer, which mark the degree of heat neceſſary to fuſe caſt-iron, correſpond to 17977 degrees above zero of Fahrenheit's ſcale; for the zero of the pyrometer correſponds to 1077 degrees above zero of Fahrenheit's thermometer. The degrees of heat neceſſary for melting the different metals and ſemi-metals, as here indicated, are thoſe then which

would

would be marked by the mercurial thermometer, if the ſcale were of ſufficient extent for that purpoſe.

I have not mentioned the degrees neceſſary to fuſe arſenic, titanium, chrome, and tellurium, as theſe four have never yet been ſubjected to trial; nor have I indicated the exact degree neceſſary to fuſe copper, becauſe it appears that there is an error in the reſults which have been given; ſince, according to theſe, copper would melt at a degree of heat leſs than that neceſſary for fuſing gold and ſilver; but the contrary is the caſe, as I have myſelf found by expoſing theſe three metals to the focus of Trudaine's burning glaſs. Silver was always fuſed by it ſooneſt; then gold; and, in the laſt place, copper, which required to be longer expoſed, and in ſmaller quantity, for I brought a crown of ſix francs into perfect fuſion in half a minute; and a much longer time was neceſſary to fuſe a piece of copper of ſix deniers, though conſiderably ſmaller.

Degrees of Wedgewood's Pyrometer.		Degrees of Fahrenheit's Thermometer.
	Mercury	40 below zero
	Tin —	378 above zero
	Biſmuth —	461·25
	Lead —	562·5
	Zinc —	666
	Antimony	776·25
28	Silver —	4717
32	Gold —	5237
37	Copper	5886, or nearly
130	Nickel	17976, or nearly
130	Cobalt	17976, or nearly
130	Caſt-iron	17977
160	Manganeſe	21877·065
more than 160	Tungſten	21877·065, and more
more than 160	Molybdena	21877·065, and more
174½	Platina	23762·072, commencement of fuſion
	Arſenic	unknown.
	Titanium	
	Chrome	
	Tellurium	

791. *Hardneſs of the Metals in the decreaſing Order.*

Iron
Platina
Copper
Silver
Gold
Tin
Lead.

792. *Hardneſs of the Semi-metals in the decreaſing Order.*

Manganeſe
Nickel
Biſmuth
Tungſten
Zinc
Cobalt
Antimony
Arſenic
Molybdena
Titanium
Chrome
Tellurium.
} unknown

793. *Tenacity of the Metals in the decreaſing Order.*

The tenacity of lead being eſtimated at *one*, the following numbers ſhew how many times the tenacity of the other metals equals that of lead:

Iron	—	26·447
Copper	—	14·555
Platina	—	13·209
Silver	—	9·011
Gold	—	7·226
Tin	—	1·667
Lead	—	1·000

794. *Elaſticity of the Metals in the decreaſing Order.*

Iron
Copper
Platina
Silver
Gold
Tin
Lead.

795. *Sonorous Property of Metals in the decreaſing Order.*

Copper
Silver
Iron
Tin
Platina
Gold
Lead.

796. *Gravity of the Metals and Semi-metals ſimply fuſed, in the decreaſing Order.*

Purified Platina		195000
Gold	—	192581
Mercury	—	135681
Lead	—	113523
Silver	—	104743
Biſmuth	—	98227
Cobalt	—	78119
Nickel	—	78070
Copper	—	77880
Tin	—	72914
Caſt-iron	—	72070
Zinc	—	71908
Manganeſe	—	68500

Antimony

Antimony — 67021
Tungſten — 66785
Tellurium — 61150
Molybdena — 60000 nearly
Arſenic — 57633
Titanium } unknown.
Chrome }

797. *Oxidability of the Metals and Semi-metals in the decreaſing Order.*

By *oxidability* is not meant the quantity of oxygen which metals are ſuſceptible of receiving, but the facility with which they become oxidated. The firſt five become oxidated nearly with the ſame facility.

Iron
Nickel
Cobalt
Zinc
Manganeſe
Lead
Tin
Copper
Biſmuth
Antimony
Arſenic
Mercury
Silver
Gold
Platina
Tungſten }
Molybdena }
Titanium } unknown.
Chrome }
Tellurium }

798. *In-*

798. *Increaſe of Weight which the Metals and Semi-Metals acquire by Oxidation, in the decreaſing Order.*

Iron	0·70	Lead	0·16	
Manganeſe	0·68	Silver	0·12	
Zinc	0·61	Gold	0·10	
Copper	0·58	Mercury	0·08	
Cobalt	0·40	Arſenic		unknown.
Chrome	0·40	Tungſten		
Antimony	0·38	Molybdena		
Tin	0·30	Titanium		
Nickel	0·28	Platina		
Biſmuth	0·25	Tellurium		

799. *Affinity of the Metals and Semi-Metals for Acids, in the decreaſing Order.*

Zinc	Arſenic	
Iron	Mercury	
Manganeſe	Silver	
Cobalt	Gold	
Nickel	Platina	
Lead	Tungſten	unknown.
Tin	Molybdena	
Copper	Titanium	
Biſmuth	Chrome	
Antimony	Tellurium	

800. *Acid-*

800. *Acidification of the Semi-metals.*

Arſenic, which becomes Arſenic acid
Molybdena — Molybdic acid
Tungſten — Tungſtic acid
Chrome — Chromic acid.

801. *Adheſion of the Metals and Semi-metals to Mercury, in the decreaſing Order.*

The adheſion of cobalt to mercury being eſtimated at *one*, the following numbers indicate how many times the adheſion of the other metals equals that of cobalt.

Gold	—	55¾	Cobalt	1
Silver	—	53⅛	Nickel	unknown.
Tin	—	52¼	Arſenic	
Lead	—	49⅝	Mangaueſe	
Biſmuth		46½	Tungſten	
Platina	—	35¼	Molybdena	
Zinc	—	25½	Titanium	
Copper	—	17¾	Chrome	
Antimony		15¾	Tellurium	
Iron	—	14⅜		

Nature and Formation of the Acids.

802. All the *acids* are compoſed of a ſubſtance either ſimple or compound, called their *Radical*, which

which ſerves them as a baſe, and which is combined with oxygen (360) that renders it acid.

803. Every time therefore that you combine oxygen with any baſe, you form an acid. *Acid* is the generic name of all theſe compounds, and each acid is diſtinguiſhed from the reſt by its baſe or *radical.*

804. A part of the combuſtible bodies, and in general all bodies capable of becoming acids, are ſuſceptible of different degrees of oxygenation. The acids which thence reſult, though formed by the combination of two ſubſtances abſolutely the ſame, may have very different properties, which depend on the difference in the proportions of the oxygen which has entered into their compoſition.

Mineral Acids.

805. *Acid of Sulphur.* This acid is obtained by the combuſtion of ſulphur, which is its radical. The ſulphur in burning combines with the oxygen of the atmoſphere, and by theſe means becomes acid. This acid formerly was known under the name of the Vitriolic, becauſe it was extracted from vitriol of iron: chemiſts were then ignorant that it was the ſame as that obtained by the combuſtion of ſulphur. It is ſuſceptible of ſeveral degrees of oxygenation. Sulphur combined with a little oxygen forms *oxide of ſulphur*, called *Soft Sulphur.* By a

ſecond degree of oxygenation it forms a volatile acid of a penetrating odour, which has peculiar properties, and is called *Sulphurous Acid:* it is ſoluble in water in a very large quantity. By a third degree of oxygenation it forms a fixed acid, ponderous, inodorous, and which in its combinations gives products very different from thoſe of the preceding: it is called *Sulphuric Acid.*

806. *Acid of Nitre.* This acid was the firſt in which the exiſtence of oxygen was fully proved. It has for its radical azote (144) which is ſuſceptible of ſeveral degrees of oxygenation. By the firſt degree it becomes the baſe of nitrous gas (70) which is inſoluble in water: in this caſe there are two parts of oxygen for one of azote. By the ſecond degree of oxygenation it becomes *nitrous acid*, which is red, fuming, of a penetrating odour, and perfectly ſoluble in water: there are then three parts of oxygen for one of azote. By the third degree of oxygenation, in which there are four parts of oxygen for one of azote, it becomes *nitric acid*, which is white, ſoluble in water, more fixed and leſs odorous than the preceding, and in which the principles are more firmly combined. This acid may be obtained from ſaltpetre, ſubjected to the action of ſulphuric acid.

807. *Acid of Marine Salt.* This acid is procured by pouring ſulphuric acid over marine ſalt; a ſtrong efferveſcence immediately takes place, and there

ariſe vapours of an exceedingly penetrating odour: theſe vapours are the acid, which may be entirely diſengaged by expoſing the mixture to a gentle heat: it is known by the name of the *Muriatic Acid.* We are unacquainted with its baſe, becauſe it is not poſſible to procure it alone and ſeparated from oxygen: it has been called the *Muriatic Radical.* This acid paſſes off in the form of gas, and naturally maintains itſelf in that ſtate, provided it does not meet with water, in which it is perfectly ſoluble; and in that caſe it forms *liquid muriatic acid.* To collect it very pure, the ſalt exceedingly dry muſt be put into a ſmall retort along with the ſulphuric acid, and the beak of the retort muſt be introduced below a bell filled with mercury, over a pneumatic apparatus. It may be obtained, on a large ſcale, by means of an apparatus compoſed of ſeveral bottles, each having two or three tubulures. The muriatic radical is ſuſceptible of ſeveral degrees of oxygenation. By the firſt it forms *muriatic oxide*; by the ſecond, *weak muriatic acid*; by the third, *muriatic acid*; and by the fourth, *oxygenated muriate.*

808. The exceſs of oxygen which this acid contains, in the fourth degree, produces on it an effect different from what it produces on the other acids: it renders it more volatile and leſs miſcible with water; gives it a more penetrating ſmell, and greatly diminiſhes and even deſtroys its acidity (208).

809. *Acid of Charcoal.* This acid is obtained by burning charcoal in pure air, by means of a mercurial apparatus. The carbonaceous principle, or carbon, is ſuſceptible of being oxygenated to ſuch a degree as to become acid; it then forms the acid in queſtion, and which for this reaſon has been called the *Carbonic Acid.* This acid remains in the gaſeous ſtate at every temperature (212); it is however ſoluble in water, but only in ſmall quantity: the coldeſt water, which can diſſolve more of it than warm water, diſſolves only a volume equal to its own. This acid is often found in the ſtate of gas; it is found alſo in that of mixture, as in mineral waters; and in that of combination, as in alkalies, marble, limeſtone, &c.

810. *The Acid of Phoſphorus.* Phoſphorus is a ſimple combuſtible ſubſtance, extracted from the bones of animals (21) which are real phoſphate of lime. It combines with oxygen by combuſtion, and forms *phoſphorous acid,* if not ſaturated with oxygen; but in the contrary caſe, that is when ſaturated with oxygen, it forms *phoſphoric acid.*

811. *The Acid of Sparry Fluor.* Sparry fluor is a ſubſtance compoſed of a peculiar acid, combined with a calcareous baſe. This acid is completely formed in ſparry fluor; it may be eaſily diſengaged from it by means of the ſulphuric acid (805) which takes from it its baſe: the acid, which is called

Fluoric Acid, remains then free. Its radical, called the Fluoric Radical, is entirely unknown, becauſe this acid has never yet been decompoſed. It poſſeſſes the property of diſſolving glaſs. Puymorin therefore has engraved on glaſs with this acid, in the ſame manner as artiſts engrave on copper with the nitric acid.

812. *Acid of Borax.* Borax is a ſubſtance compoſed of a peculiar acid, combined with a baſe. This acid is completely formed in borax, and may be diſengaged from it by means of the ſulphuric acid (805) which takes from it its baſe: the acid then remains free, and is what is called the *Boracic Acid.* Its radical, called the *Boracic Radical*, is entirely unknown; becauſe it is impoſſible to decompoſe this acid, and to obtain its radical diſengaged from the oxygen by which it is acidified.

Metallic Acids.

813. The metals and ſemi-metals are ſuſceptible of combining with oxygen; but we are acquainted with only a ſmall number capable of being ſo far oxygenated as to become *acids:* in regard to the reſt, the degrees of oxygenation which they are ſuſceptible of, make them only oxides, known before by the name of *Metallic Calces.* The following is a liſt of them:—

	Degrees of Oxygenation.
814. Gold — —	1, oxide of gold
815. Platina — —	1, oxide of platina
816. Silver — —	1, oxide of ſilver
817. Copper —	1, reddiſh brown oxide of copper
	2, green and blue oxide of copper
818. Iron — —	1, black oxide of iron
	2, reddiſh brown oxide of iron
819. Tin — —	1, grey oxide of tin
	2, white oxide of tin
820. Lead — —	1, grey oxide of lead
	2, yellow and red oxide of lead
821. Mercury —	1, black oxide of mercury
	2, yellow and red oxide of mercury
822. Biſmuth —	1, grey oxide of biſmuth
	2, white oxide of biſmuth
823. Cobalt — —	1, grey oxide of cobalt
824. Nickel — —	1, oxide of nickel
825. Zinc — —	1, grey oxide of zinc
	2, white oxide of zinc
826. Antimony —	1, grey oxide of antimony
	2, white oxide of antimony
827. Manganeſe —	1, black oxide of manganeſe
	2, white oxide of manganeſe
828. Titanium —	1, oxide of titanium
829. Tellurium —	1, oxide of tellurium
830. Arſenic —	1, grey oxide of arſenic
	2, white oxide of arſenic
	3, arſenic acid
831. Tungſten —	1, oxide of tungſten
	2, tungſtic acid
832. Molybdena —	1, oxide of molybdena
	2, Molybdic acid
833. Chrome —	1, green oxide of chrome
	2, chromic acid

Vegetable Acids.

834. All the *vegetable acids* ſeem to be formed of a double acidifiable baſe, viz. carbon (20,381 *et ſeq.*) and hydrogen (276); their radical therefore is carbono-hydrous or hydro-carbonous, acidified by its combination with oxygen. Theſe acids, according to every appearance, differ from each other only by the different proportions of the carbon and hydrogen, and the difference in the quantity of oxygen by which they are acidified.

835. Theſe acids, with their radicals, are as follows:—

Radicals.	*Acids.*	
The acetic	Acetous Acetic	Vinegar
Malic	Malic	Apples
Oxalic	Oxalic	Sorrel
Citric	Citric	Lemons
Tartaric	Tartareous	Tartar
Pyro-tartaric	Pyro-tartareous	The empyreuma of tartar
Pyro-mucic	Pyro-mucous	The empyreuma of ſugar
Pyro-lignic	Pyro-ligneous *	The empyreuma of wood
Benzoic	Benzoic	Flowers of benjamin
Camphoric	Camphoric	Camphor
Gallic	Gallic	The aſtrigent principle of vegetables
Succinic	Succinic	Volatile ſalt of amber

The

---

* The pyro-tartareous, pyro-mucous, and pyro-ligneous acids have, ſince the publication of the preſent work, been

proved

The nature of the four laſt radicals is as yet but imperfectly known: we know only that their principal conſtituent parts are carbon and hydrogen.

Animal Acids.

836. The *animal acids* are thoſe obtained by oxygenating animal matters. All theſe acids (the phoſphorous and phoſphoric excepted (810) the radical of which is a ſimple ſubſtance) ſeem to have for their acidifiable baſe carbon, hydrogen, phoſphorus, and azote. Theſe acids are as follows:—

Radicals.	*Acids.*	
The phoſphoric	Phoſphorous Phoſphoric	Phoſphorus
Sebacic	Sebacic	Fat
Formic	Formic	Ants
Bombic	Bombic	Silk-worms
Lactic	Lactic	Sour whey
Saccho-lactic	Saccho-lactic	Sugar of milk
Lithic	Lithic	Human calculus
Pruſſic	Pruſſic	The colouring matter of Pruſſian blue

---

proved to be only *acetic acid*, rendered impure by empyreumatic oil. For an account of the experiments upon this ſubject, ſee Bouillon Lagrange's Chemiſtry, Engliſh edition, Appendix; and the Philoſophical Magazine, vol. viii, p. 40.

The nature of the four laſt radicals is as yet but imperfectly known; we know only that azote is a conſtituent part of the pruſſic radical.

837. Though the vegetable acids are compoſed of hydrogen, carbon, and oxygen, they contain neither water, oil, nor carbonic acid, but only the principles proper for forming them. The attractive force reciprocally exerciſed by theſe three ſubſtances on each other, is in theſe acids in a ſtate of equilibrium, which ceaſes to exiſt when they are expoſed to a degree of heat greater than that of boiling water. The oxygen and the hydrogen then combine together to form water (278 *et ſeq.*); the carbon and hydrogen combine to form oil; and a portion of the carbon and oxygen, by combining, form carbonic acid: there is found alſo a ſmall exceſs of carbon which remains free (855).

838. Thirty-four acids therefore are known, viz. twelve mineral acids (805—833); thirteen vegetable acids (834, 835); and nine metallic acids (836).

839. Theſe acids become neutralized by uniting and combining with ſome baſe, either alkaline, ſuch as potaſh (842) ſoda (843) ammonia (847); or earthy, as lime (404) magneſia (411) barytes (416) alumine (421) ſtrontian (429) &c.; or metallic, as the different ſemi-metals.

Of Alkalies.

840. The alkalies are divided into *fixed* and *volatile alkalies.* The former have no odour; the latter have a pungent and penetrating odour.

841. We are acquainted with two kinds of fixed alkalies, viz. vegetable alkali, or *potaſh*, and mineral alkali, or *ſoda.*

842. Vegetable alkali, or potaſh, may be extracted from different ſubſtances: when extracted from the lixivium of wood-aſhes, and afterwards calcined, it is real potaſh. Potaſh readily combines with fat ſubſtances, and renders them ſoluble in water: this combination forms *ſoap.* Wine-lees may be reduced almoſt entirely into alkali by combuſtion: this is what is called *Weed-Aſhes.* This alkali is greeniſh, and is conſidered as exceedingly pure. The combuſtion of wine-ſtone alſo furniſhes very pure alkali, but neutralized: it is known under the name of *Carbonate of Potaſh*, or *Salt of Tartar.* Vegetable alkali, when very pure, attracts the moiſture of the air, and reſolves itſelf into a liquid.

843. Mineral alkali, or *ſoda*, is the baſe of the muriate of ſoda, or ſea-ſalt. It is generally extracted from marine plants by combuſtion. *Saltwort*, a plant which grows in Provence and in Languedoc, on the

borders of ponds, furniſhes ſoda of an excellent quality. The beautiful ſoda of Alicant is procured from the barilla of Spain. Mineral alkali is ſometimes found in a native ſtate: it is found alſo in Egypt, where it is known under the name of *Natron* or *Natrum*: it is real *carbonate of ſoda*.

844. Mineral alkali differs from the vegetable, 1ſt, By being leſs cauſtic; 2d, By effloreſcing in the air inſtead of attracting its moiſture; 3d, By forming with the ſame baſes different products; 4th, By cryſtallizing in rhomboidal octaedra, and by being fitter for promoting vitrification.

845. Are alkalies completely formed in vegetables? or, are they the product of combuſtion? The former is the moſt probable; but on this point nothing certain is known.

846. The fixed alkalies, by their combination with carbonic acid (809) are often in the ſtate of neutral ſalts; but they may be diſengaged from the acid by quick-lime. The lime unites to the aci, and forms chalk (459) and the alkali becomes pure and cauſtic. This alkali, when evaporated to dryneſs, is the *cauſtic ſtone* uſed in ſurgery.

847. Volatile alkali, or *ammonia*, is produced by the putrefaction of animal ſubſtances, for it is compoſed of azote (374) and hydrogen (379) which are

conſtituent

conſtituent parts of animals (836). According to Berthollet, they contain 807-thouſandth parts of azote, and 193-thouſandth parts of hydrogen. Some plants alſo furniſh volatile alkali, and for that reaſon they are called *Animal Plants.*

848. The volatile alkali of the ſhops is obtained by the decompoſition of the muriate of ammonia; and on this account volatile alkali has been called *Ammonia.* When combined with carbonic acid, it forms *carbonate of ammonia.*

Formation of the Neutral Salts.

849. We have already ſhewn (354 *et ſeq.*) in what manner ſome ſimple ſubſtances (or ſubſtances conſidered as ſuch, becauſe they have never yet been decompoſed, as azote, hydrogen, carbon, ſulphur, phoſphorus, &c.) by combining with oxygen, form all the oxides and acids of the vegetable and animal kingdoms. It has been ſeen by what ſimple means Nature multiplies properties and forms, either by combining three or four acidifiable baſes and in different proportions, or by varying the doſe of oxygen deſtined for their acidification: we ſhall find that ſhe exhibits no leſs ſimplicity, variety, and fecundity in the production of *neutral ſalts.*

850. The acidifiable ſubſtances being converted into acids by combining with oxygen, acquire a

great tendency to combination; they become ſuſceptible of uniting with alkaline, earthy, and metallic ſubſtances, and the reſult of this union is *neutral ſalts*. Acids therefore may be conſidered as *ſalifying principles*, and the ſubſtances to which they unite as *ſalifiable baſes*. It is of theſe combinations we are now going to treat.

851. We ſhall not therefore conſider the acids as ſalts, though, like them, they are ſoluble in water. The acids reſult from a combination of the firſt order: they are formed by the union of two ſimple principles, or at leaſt of principles which appear to be ſo, and conſequently they belong to the order of mixtures.

852. The neutral ſalts belong to another order of combination: they are formed by the union of two mixtures, and enter into the claſs of compounds.

853. Neither ſhall we place the alkalies and earthy ſubſtances in the claſs of ſalts:—We ſhall conſider as ſalts thoſe compounds only which are formed by the union of a ſimple oxygenated ſubſtance with ſome baſe. This ſimple oxygenated ſubſtance, when without a baſe, is but an acid.

854. There are ſeveral baſes ſuſceptible of combining with acids to form neutral ſalts. Theſe baſes, which are called *ſalifiable*, are the alkalies

(840

(840 *et ſeq.*) viz. potaſh, ſoda, and ammonia; the primitive earths (401 *et ſeq.*) viz. lime, magneſia, barytes, alumine, ſilex, ſtrontian, zirconia, glucina, and metallic ſubſtances. (573 *et ſeq.*) We ſhall now proceed to examine the origin and nature of theſe ſubſtances.

855. *Potaſh.* When a vegetable ſubſtance is expoſed to heat in an alembic, its three principles, oxygen, hydrogen, and carbon, which formed a triple combination when in a ſtate of equilibrium, unite two and two, according to the degree of temperature. As ſoon as the heat exceeds that of boiling water, the oxygen and hydrogen combine and form water (278 *et ſeq.*); ſoon after, the carbon and hydrogen unite and form oil. By a red heat this oil and water are decompoſed: the oxygen and carbon form carbonic acid; the hydrogen, become free, eſcapes under the form of gas in a large quantity, and nothing remains in the retort but charcoal: the reſults then are, 1ſt, water; 2d, oil; 3d, carbonic acid; 4th, hydrogen gas; 5th, charcoal.

856. The greater part of theſe phenomena take place during the combuſtion of vegetables in the open air; but, in this caſe, the preſence of the air introduces other ingredients, viz. the oxygen of the air, azote, and caloric. In proportion as the hydrogen of the vegetable, or of the water, eſcapes under the form

form of gas, it immediately inflames by the contact of the air, and re-forms water by combining with the oxygen of that air; and the caloric of theſe two fluids, which becomes free, at leaſt for the greater part, produces flame. When all the hydrogen gas has been burnt and reduced to water, the charcoal which remains burns in its turn, but without flame. By its union with the oxygen of the air, it forms carbonic acid; and by combining with caloric, eſcapes under the gaſeous form. The ſurplus of the caloric becoming free, produces that heat and light obſerved during the combuſtion of charcoal.

857. The vegetable is thus totally reduced into water and carbonic acid; nothing remains but a ſmall quantity of a grey earthy matter, known under the name of *Aſhes*, and which contain the only real fixed principles that enter into the conſtitution of vegetables. Theſe aſhes, which in weight are equal to no more than a twentieth part of that of the vegetable, contain a peculiar ſubſtance, called *Fixed Vegetable Alkali*, or *Potaſh.* It is not yet known whether this potaſh exiſts completely formed in the vegetable, or whether it is produced during the operation.

858. To obtain potaſh, water is made to paſs through the aſhes: the water becomes charged with the potaſh, which is ſoluble in that fluid, and leaves the

the aſhes, which are inſoluble. By evaporating the water you will then obtain the potaſh, which is fixed, even at a very ſtrong degree of heat, and which remains white, and under a concrete form. The potaſh obtained by this proceſs is more or leſs ſaturated with carbonic acid, the reaſon of which is as follows:—In forming itſelf, or even if it be already formed, as it becomes free on'y in proportion as the carbon is converted into carbonic acid, by its combination with the oxygen of the air, or of the water, the reſult is, that the potaſh at the moment of its formation, or of its being ſet at liberty, finds itſelf in contact with carbonic acid, for which it has a great affinity; a combination therefore muſt take place between theſe two ſubſtances.

859. To free the potaſh from this carbonic acid it muſt be diſſolved in water, and twice or thrice its weight of quicklime muſt be added to the ſolution. If the liquor be then evaporated in cloſe veſſels, you will obtain pure potaſh. In this ſtate, it is not only ſoluble in water, at leaſt weight for weight, but it attracts, with great avidity, the moiſture of the air, and of the gaſes; and this furniſhes us with a method of drying thoſe which are expoſed to it. It is ſoluble alſo in alcohol; but not when it is ſaturated with carbonic acid.

860. It is probable that the aſhes exiſted in the vegetable before its combuſtion. This earth, ac-

cording to every appearance, forms the ſkeleton of the vegetable.

861. *Soda.* This ſubſtance, like potaſh, is an alkali obtained by lixiviating the aſhes of certain plants which grow on the borders of the ſea, and chiefly of the *Kali*; from which it has been called *Alkali*; a name given to it by the Arabs. Soda has ſome properties common to potaſh; and others by which it is peculiarly diſtinguiſhed. Soda for the moſt part is ſaturated with carbonic acid; but it does not, like potaſh, attract the moiſture of the air; on the contrary, when expoſed to the air, it becomes dry, its cryſtals effloreſce, and are converted into a white powder, which differs from cryſtallized ſoda only in having loſt its water of cryſtallization.

862. We are as little acquainted with the conſtituent principles of ſoda as with thoſe of potaſh. We are ignorant whether it exiſts completely formed, or not, in vegetables before their combuſtion. From analogy, however, we might be induced to believe that azote (373 *et ſeq.*) is one of the principles of alkalies in general, as we ſhall prove in regard to the volatile alkali or ammonia.

863. *Ammonia.* Berthollet has proved, by the way of decompoſition *, that 1000 parts of Ammonia

---

* Memoires de l'Academie des Sciences 1785, p. 316.

monia in weight, are compoſed of 807 parts of azote, and 193 parts of hydrogen. Ammonia is obtained chiefly by the diſtillation of animal ſubſtances. The azote, which is one of their conſtituent principles, unites itſelf to the hydrogen in the proper proportion, and ammonia is formed. But it is then mixed with water and oil, and is in a great part ſaturated with carbonic acid.

864. To free ammonia from all theſe ſubſtances, it muſt firſt be combined with an acid; ſuch, for example, as the muriatic, and afterwards be diſengaged from it by the addition of lime, or of potaſh. After this proceſs it is exceedingly pure. In its ſtate of purity it can exiſt only under the gaſeous form at our common temperature. It has a very penetrating odour: it is abſorbed in a very large quantity, by water, eſpecially if the latter be very cold; and in that ſtate it forms *liquid ammonia*, or *volatile fluor alkali*.

865. As *the primitive earths* (401) cannot be decompoſed, we are unacquainted with their conſtituent parts, and therefore they are conſidered as ſimple ſubſtances. They are always exhibited to us by nature completely formed; but, as they have a great tendency to combination, they are never found alone, being always united to ſome other ſubſtances.

866. *Lime* (404 *et ſeq.*) is almoſt always ſaturated with carbonic acid; in which caſe it forms chalk,

calca-

calcareous ſpar, marble, &c. Sometimes it is ſaturated with ſulphuric acid, as in gypſum and plaſter-ſtones, or calcareous ſulphates. At other times it is combined with fluoric acid, and forms ſparry fluor, or fluate of lime. The waters of the ſea and ſaline ſprings contain ſome of it combined, with muriatic acid. In a word, of all the ſalifiable baſes, lime is that moſt abundantly diſperſed throughout nature.

867. *Magneſia* is found in a great many of the mineral waters, where, for the moſt part, it is combined with ſulphuric acid: it has been found in ſea-water combined with muriatic acid. It enters into the compoſition of a great many kinds of ſtone.

868. *Barytes* is much leſs abundant than the two preceding earths: it is found combined with ſulphuric acid, and it then forms ſulphate of barytes, known under the name of *Ponderous Spar*: ſometimes, but rarely, it is combined with carbonic acid.

869. *Alumine* has leſs tendency to combination than the preceding; and for this reaſon it is often found uncombined with any acid. It is found chiefly in the different kinds of clay (421) of which it forms the baſe. When combined with ſulphuric acid, it forms a ſulphate of alumine, known under the name of *Alum*.

870. *Silex* is found chiefly in rock-cryſtal, of which it forms the greater part, and in this mineral it is almoſt always in a ſtate of purity (425). It is found alſo ſometimes mixed with argil (421).

871. *Strontian* has ſeldom yet been found but in combination with carbonic acid. It has been found in different parts of Scotland (429) and it is not improbable that it will be found in other places: it has been found indeed lately at Montmartre combined with ſulphuric acid, and in the neighbourhood of Briſtol.

872. *Zirconia* is an earth which hitherto has been found only in the jargon of Ceylon; of which it is one of the principal conſtituent parts, and even the moſt abundant (442).

873. *Glucina* is a primitive ſimple earth, which as yet has been found only in the occidental *aigue-marine* (448). It unites readily with acids.

874. *Metallic Subſtances* are all ſuſceptible of combining with at leaſt ſome of the acids. The metals, if we except gold, platina, and ſometimes ſilver, rarely preſent themſelves in the mineral kingdom under the metallic form: in general they are more or leſs ſaturated with oxygen, or combined with ſulphur, arſenic, ſulphuric acid, muriatic acid, carbonic acid, phoſphoric acid, &c. Metallurgy

and aſſaying teach us the art of ſeparating all theſe ſubſtances. It is probable that we are not yet acquainted with all the metallic ſubſtances which exiſt in nature; for new ones are from time to time diſcovered; ſuch as titanium (740) chrome (759) tellurium (769) which have not been long known. Such of theſe metallic ſubſtances as have more affinity for oxygen than for carbon, cannot be reduced to the metallic ſtate: they never preſent themſelves but in the form of oxides, which are often confounded with earths. It may be poſſible that barytes (416) conſidering its great weight, may be in this ſtate.

875. As yet, we are acquainted with only twenty ſubſtances, which can be obtained under the metallic form, viz. ſeven metals and thirteen ſemi-metals. The metals are gold, ſilver, platina, copper, iron, tin, and lead. The ſemi-metals are mercury, biſmuth, cobalt, nickel, zinc, antimony, arſenic, manganeſe, tungſten, molybdena, titanium, chrome, and tellurium.

876. Such are the ſalifiable baſes or ſubſtances ſuſceptible of combining with acids: they are in number thirty-one, viz. three alkalies (855, 864) eight earths (865, 873) and twenty metallic ſubſtances (875): but the alkalies and earths enter into the compoſition of neutral ſalts without any uniting medium; whereas the metals do not combine

bine with acids unleſs they have been firſt more or leſs oxygenated: we may therefore ſay, that the metals are not ſoluble in acids, but only the metallic oxides.

877. When a metallic ſubſtance, then, is put into an acid, the firſt requiſite, in order that it may diſſolve, is, that it be ſuſceptible of becoming oxidated in it. For this purpoſe, it muſt take up oxygen either from the acid, or from the water with which the acid is diluted: the oxygen then muſt have more affinity for the metal than it has either for the hydrogen or for the baſe of the acid; and, conſequently, a decompoſition either of the water or of the acid muſt take place.

878. On theſe obſervations the explanation of the principal phenomena of metallic ſolutions depends. Of theſe phenomena there are four: The firſt is effervefcence, or the diſengagement of gas, which ſometimes takes place during the ſolution: the ſecond is the non-effervefcence when the metals have been previouſly oxidated: the third is, that no metal diſſolves with effervefcence in oxygenated muriatic acid: the fourth is, that the metals which have little affinity for oxygen are not ſoluble in acids.

879. *Firſt Phenomenon.* In metallic ſolutions, n effervefcence often takes place, or, what is the

ſame thing, a diſengagement of gas. This gas, in ſolution by nitric acid, is nitrous gas (191 *et ſeq.*): in ſolutions by ſulphuric acid, it is ſulphurous acid gas, if it be this acid that has furniſhed the oxygen (242); but it is hydrogen gas if the oxygen has been furniſhed by the water (287). Nitric acid and water being compoſed of ſubſtances which, taken ſeparately, cannot exiſt but in the ſtate of gas; as ſoon as they are deprived of their oxygen, the other principle aſſumes the gaſeous form. It is this rapid paſſage from the liquid to the gaſeous ſtate that conſtitutes effervescence: the caſe is the ſame with the ſulphuric acid. In general, the metals do not take from theſe acids all their oxygen; they do not reduce the one to azote and the other to ſulphur, but to nitrous oxide and ſulphurous acid, which cannot exiſt but in the ſtate of gas.

880. *Second Phenomenon.* Metallic ſubſtances diſſolve without effervescence when they have been previouſly oxidated; for, in that caſe, the metal no longer has a tendency to decompoſe either the acid or the water. There is therefore no diſengagement of gas, and conſequently no effervescence.

881. *Third Phenomenon.* No metal diſſolves with effervescence in oxygenated muriatic acid. In this caſe, the metal takes from the acid its exceſs of oxygen, and the reſult is a metallic oxide, and ſimple muriatic acid. There is no effervescence, becauſe

becauſe there is no diſengagement of gas. The muriatic acid has a tendency to the gaſeous ſtate, but it finds more water than is neceſſary to diſſolve it: after being firſt combined with water, it afterwards combines quietly with the metallic oxide, which it diſſolves.

882. *Fourth Phenomenon.* Metals which have very little affinity for oxygen, and which have not power to decompoſe either the acid or the water, are inſoluble in acids, unleſs they have been firſt oxidated. For this reaſon, ſilver, mercury, and lead, are not ſoluble in muriatic acid when expoſed to it in their metallic ſtate: but, if previouſly oxidated, they are exceedingly ſoluble, and the ſolution takes place without efferveſcence.

883. Oxygen then is the uniting medium between metals and the acids; and hence there is reaſon to believe that ſubſtances which have a great affinity for acids contain oxygen. It is therefore probable that the ſaline earths before mentioned (866 *et ſeq.*) contain oxygen. May they not be oxidated metals, for which oxygen has more affinity than it has for charcoal, and which, on that account, may be irreducible?

884. We ſhall here preſent the reader with a table of all the acids hitherto known, and of the acidifiable baſes, or radicals, which enter into their compoſition.

885. *Mineral Acids.*	*Radicals.*
Sulphurous	Sulphur
Sulphuric	
Nitrous	Azote
Nitric	
Muriatic	Muriatic radical
Oxygenated Muriatic	
Carbonic	Carbon
Fluoric	Fluoric radical
Boracic	Boracic radical.

886. *Metallic Acids.*	*Radicals.*
Arſenic	Arſenic
Tungſtic	Tungſten
Molybdic	Molybdena
Chromic	Chrome.

887. *Vegetable Acids.*	*Radicals.*
Acetous	All theſe acids ſeem to have for their acidifiable baſe carbon and hydrogen, which gives them a double radical; and it appears that they differ from each other only by the difference in the proportions of theſe two baſes, and of the oxygen by which they are acidified. The nature of the radicals of the laſt four acids is but imperfectly known.
Acetic	
Malic	
Oxalic	
Citric	
Tartareous	
Pyro-tartareous	
Pyro-mucous	
Pyro-ligneous	
Benzoic	
Camphoric	
Gallic	
Succinic	

888. *Animal Acids.*	*Radicals.*
Phoſphorous —	Phoſphorus
Phoſphoric — —	
Formic — —	Theſe acids, and all thoſe obtained by oxygenating animal matters, ſeem to have for acidifiable baſe, carbon, hydrogen, phoſphorus, and azote, which gives them a quadruple radical.
Bombic — —	
Sebacic — —	
Lactic — —	
Saccho-lactic —	
Lithic — —	
Pruſſic — —	

889. It is here ſeen that the number of the acids is thirty-four, including the four metallic acids (886). The number of the ſalifiable baſes (854, 876) being thirty-one, it may readily be conceived that there are a great number of different neutral ſalts.

890. *A Table of the Combinations of the Sulphurous and Sulphuric Acids with the Salifiable Baſes, in the decreaſing Order.*

Barytes
Potaſh
Soda
Lime
Magneſia
Ammonia
Alumine
Strontian
Glucina,
Oxide of zinc
Oxide of iron
Oxide of manganeſe
Oxide of cobalt
Oxide of nickel
Oxide of lead
Oxide of tin
Oxide of copper
Oxide of biſmuth
Oxide of antimony
Oxide of tellurium
Oxide of arſenic
Oxide of mercury
Oxide of ſilver
Oxide of gold
Oxide of platina

All the ſalts formed by theſe acids, are called *Sulphites*, or *Sulphates*.

891. The *ſulphurous acid* is an acid of ſulphur, but not ſaturated with oxygen; or it is ſulphuric acid which has loſt part of its oxygen. It is obtained then, 1ſt, by diſtilling ſulphuric acid from off ſilver, antimony, lead, mercury, or charcoal. A portion of the oxygen of the acid unites irſelf to the metal, and the acid paſſes off in the ſtate of ſulphurous acid gas (241 *et ſeq.*). This acid is abſorbed by water in a greater quantity than carbonic acid gas (217) but in leſs quantity than muriatic acid gas (230).

892. As ſulphurous acid has only a ſmall portion of oxygen, it cannot furniſh any of it to metals; it is therefore incapable of diſſolving them, unleſs they have been firſt oxidated. But the metallic oxides diſſolve in it with facility, and even without efferveſcence, for there is no diſengagement of gas.

893. The *ſulphuric acid* is an acid of ſulphur ſaturated with oxygen. It is obtained by the combuſtion of ſulphur. To facilitate this combuſtion of ſulphur and its oxygenation, a little pounded ſaltpetre ought to be mixed with it: the ſaltpetre being decompoſed gives up to the ſulphur a portion of its oxygen, which facilitates its converſion into an acid.

894. In operations of this kind, on an extenſive ſcale, the mixture of ſulphur and ſaltpetre is burnt in large chambers, the ſides of which are caſed with plates of lead, and a little water is placed on the floor to collect the ſulphuric vapours. The water is afterwards put into large retorts, and diſtilled by a moderate heat: a water ſlightly acid paſſes over, and concentrated ſulphuric acid remains in the retort. This acid is tranſparent and inodorous, and its ſpecific gravity is almoſt double that of water.

895. Iron and zinc become oxidated in ſulphuric acid by decompoſing the water, and by theſe means are rendered ſoluble in the acid, though it be neither concentrated nor in a ſtate of ebullition, becauſe theſe two metals have a great affinity for oxygen.

896. Berthollet found by one experiment that ſixty-nine parts of ſulphur abſorbed, in burning, thirty-one parts of oxygen, which formed a hundred parts of ſulphuric acid. In another experiment ſeventy-two parts of ſulphur abſorbed twenty-eight parts of oxygen, and formed a hundred parts of dry ſulphuric acid.

897. *A Table of the Combinations of the Nitrous and Nitric Acids with the Salifiable Baſes, in the Order of their Affinity for theſe Acids.*

Barytes
Potaſh
Soda
Lime
Magneſia
Ammonia
Alumine
Strontian
Oxide of zinc
Oxide of iron
Oxide of manganeſe
Oxide of cobalt
Oxide of nickel
Oxide of lead
Oxide of tin
Oxide of copper
Oxide of biſmuth
Oxide of antimony
Oxide of tellurium
Oxide of arſenic
Oxide of mercury
Oxide of ſilver
Oxide of gold
Oxide of platina

The ſalts formed by theſe acids are called *Nitrites* or *Nitrates*.

898. The *nitrous* and *nitric acids* are obtained from nitre, or ſaltpetre, the baſe of which is potaſh. Saltpetre is extracted by lixiviation from the rubbiſh of old buildings, and the earth of cellars, ſtables, barns, &c. In theſe earths the nitric acid is often united to lime, magneſia, ſometimes to potaſh, and rarely to alumine. All theſe ſalts, except that which has potaſh for its baſe, and which is nitre, or ſaltpetre, attract moiſture, and are difficult to be preſerved. On this account chemiſts endeavour to bring all theſe nitric ſalts to the ſtate of ſaltpetre.

899. To extract the nitrous acid from this ſalt, put three parts of very pure ſaltpetre, and one part of concentrated ſulphuric acid into a tubulated re-

tort; adapt to the retort a balloon with two necks, and having connected the whole with Woulf's apparatus (fig. 44) lute well the joinings, and proceed to diſtillation by a graduated heat. The nitrous acid will paſs over in the form of red vapours, part of which will be condenſed in the balloon into a liquor of a dark reddiſh yellow colour, and the ſurplus will combine with the water in the bottles, L, L, &c.; at the ſame time a great deal of oxygen gas will be diſengaged, becauſe, at a pretty high temperature, oxygen has more affinity for caloric than for the nitrous oxide. The nitric acid therefore, by loſing a part of its oxygen, is converted into nitrous acid. If the exceſs of nitrous gas be expelled by a gentle heat, it may be brought back to the ſtate of nitric acid; but in that caſe the acid is much diluted with water, and there is a great deal of loſs.

900. To obtain nitric acid much more concentrated, and with leſs loſs, make a mixture of ſaltpetre and very dry clay, and expoſe it to a ſtrong heat in an earthen retort. The argil will combine with the potaſh, for which it has a great affinity; and nitric acid, containing only a little nitrous gas, will paſs over. The acid may be freed from the gas by gently heating it in a retort; a little nitrous acid will then paſs into the receiver, and the nitric acid will remain in the retort.

901. As

901. As azote is the nitric radical (885) if to 20½ parts in weight of azote you add 43½ parts of oxygen, this proportion will conſtitute *nitrous oxide* or *gas*; and if to this combination you add 36 parts more of oxygen, you will obtain nitric acid. The various degrees, between theſe two proportions, give different kinds of nitrous acid more or leſs charged with oxygen.

902. *Table of the Combinations of the Muriatic and Oxygenated Muriatic Acids with the Salifiable Baſes, in the Order of their Affinity for theſe Acids.*

Barytes
Potaſh
Soda
Lime
Magneſia
Ammonia
Alumine
Strontian
Oxide of zinc
Oxide of iron
Oxide of manganeſe
Oxide of cobalt
Oxide of nickel
Oxide of lead
Oxide of tin
Oxide of copper
Oxide of biſmuth
Oxide of antimony
Oxide of tellurium
Oxide of arſenic
Oxide of mercury
Oxide of ſilver
Oxide of gold
Oxide of platina

The order of affinity is the ſame in regard to the oxygenated muriatic acid, except that we muſt omit the ammonia, and add zirconia and the oxide of chrome.

The ſalts formed by theſe baſes, combined with the muriatic acid, are called *Muriates*; and if theſe baſes are combined with oxygenated muriatic acid, the ſalts are called *Oxygenated Muriates*. All the latter kind were diſcovered by Berthollet in 1786.

903. The

903. The muriatic acid is diffuſed in great abundance throughout the mineral kingdom, and is united chiefly with ſoda, lime, and magneſia; it is found with theſe three baſes in ſea-water, and in that of ſeveral lakes. In mines of rock-ſalt it is for the moſt part united with ſoda. We are entirely unacquainted with the radical of this acid.

904. The muriatic acid does not adhere very ſtrongly to its baſes—the ſulphuric acid is capable of ſeparating it from them; and it is by means of this acid that chemiſts obtain the former. For this purpoſe put one part of concentrated ſulphuric acid, and two parts of marine ſalt, into a tubulated retort, and adapt it to Woulf's apparatus (*fig.* 44) then pour ſulphuric acid into the retort through the tubulure; the muriatic acid will paſs over in the ſtate of gas, and unite itſelf in a large proportion with the water in the bottles, L, L, &c. The water thus ſaturated is muriatic acid.

905. This acid does not contain as much oxygen as it is capable of receiving, for it is ſuſceptible of aſſuming a new doſe if it be diſtilled from off metallic oxides, ſuch as thoſe of mangaueſe, lead, and mercury: it is then *oxygenated muriatic acid:* it then aſſumes the gaſeous form, and is ſoluble in water, but in much leſs quantity than before it was oxygenated. If the water be impregnated beyond a certain degree, the acid precipitates itſelf to the bottom of the veſſel under a concrete form.

906. Oxygenated muriatic acid may be combined with a great number of the ſalifiable baſes: the ſalts which it forms are ſuſceptible of detonating with carbon, and with ſeveral metallic ſubſtances. Theſe detonations are exceedingly dangerous, becauſe the oxygen enters into the muriate with a large quantity of caloric, which by its expanſion gives riſe to theſe violent exploſions.

910. The *nitro-muriatic acid* is a mixture of the nitric and muriatic acids, which forms a peculiar ſolvent of gold and platina, formerly called *Aquaregia.* Some conſider it as an acid with two baſes; that is to ſay, thoſe of the two acids of which it is formed. Others are of opinion that the muriatic acid ſeizes on a conſiderable part of the oxygen of the nitric acid, and becomes oxygenated muriatic acid, which alſo diſſolves gold. Lavoiſier and Berthollet however think that if this were really the caſe, nitrous gas would be diſengaged from the nitro-muriatic acid when expoſed to heat; and yet they obtained none that could be obſerved. Is it not poſſible that, in the mixture of theſe two acids, the nitric acid may be ſo deprived of its oxygen, that its radical azote is no longer ſuſceptible of aſſuming the gaſeous form? In this caſe no nitrous gas would eſcape, and the mixture would really become oxygenated muriatic acid.

911. The nitro-muriatic acid has a penetrating diſagreeable odour; and when reſpired, is as deſtructive

tive to animal life as any of the reſt. It diſſolves in water in a pretty large quantity. The order of its affinity for the ſalifiable baſes is not exactly known, unleſs it be really the ſame ſubſtance as the oxygenated muriatic acid. In the caſe of its being conſidered as an acid with two baſes, it is not known whether with earths and alkalies it forms a mixt ſalt, or whether the two acids ſeparate to form two diſtinct ſalts.

In its combinations, if it forms peculiar ſalts, they are called *Nitro-Muriates.*

912. *Table of the Combinations of the Carbonic Acid with the Salifiable Baſes, in the Order of their Affinity for that Acid.*

Barytes
Lime
Potaſh
Soda
Magneſia
Ammonia
Alumine
Strontian
Zirconia
Oxide of zinc
Oxide of iron
Oxide of manganeſe
Oxide of cobalt
Oxide of nickel
Oxide of lead
Oxide of tin
Oxide of copper
Oxide of biſmuth
Oxide of antimony
Oxide of tellurium
Oxide of arſenic
Oxide of mercury
Oxide of ſilver
Oxide of gold
Oxide of platina

All the ſalts formed by the carbonic acid are called *Carbonates*.

913. The carbonic acid is one of thoſe moſt abundantly diffuſed throughout Nature: it exiſts completely formed in chalk, marble, and calcareous ſtones, in which it is neutralized chiefly by lime. To diſengage it from theſe ſubſtances, nothing is neceſſary but to pour over them ſulphuric or any other acid, provided it has more affinity for lime than the carbonic acid, which is then diſengaged with effervescence in the form of gas. It unites with water only in about equal volumes, and the reſult is a very weak acid. Carbonic acid may be obtained alſo from ſaccharine matter in fermentation; but in that caſe it holds in ſolution a little alcohol.

914. As carbon is the radical of this acid, it may be formed by burning charcoal in oxygen gas, or by combining pounded charcoal with a metallic oxide: the oxygen of the oxide combines with the charcoal, and forms carbonic acid; and the metal becoming free, reſumes its metallic appearance. For the firſt knowledge of this acid we are indebted to Dr. Black.

915. *A Table of the Combinations of the Fluoric Acid with the Salifiable Baſes, in the Order of their Affinity for that Acid.*

Lime
Barytes
Magneſia
Potaſh
Soda
Ammonia
Oxide of zinc
Oxide of manganeſe
Oxide of iron
Oxide of lead
Oxide of tin
Oxide of cobalt
Oxide of copper
Oxide of nickel
Oxide of tellurium
Oxide of arſenic
Oxide of biſmuth
Oxide of mercury
Oxide of ſilver
Oxide of gold
Oxide of platina
Silex
and in the dry way
Alumine

All theſe ſalts, formed by the fluoric acid, and which were unknown to the old chemiſts, are called *Fluates.*

916. The *fluoric acid* exiſts completely formed in fluate of lime, known under the name of *Sparry Fluor.* It is combined in it with calcareous earth, the baſe of that ſpar, and forms with it an inſoluble ſalt. To obtain this acid alone, and ſeparated from its baſe, put ſparry fluor into a leaden retort, * and pour over it ſulphuric acid: adapt to the receiver a leaden retort, half filled with water, and expoſe the apparatus to a gentle heat. The ſulphuric acid ſeizes on the baſe of the ſpar, and forms with it a ſulphate of lime; and the fluoric acid paſſes over, and is abſorbed by the water in the receiver: if the fluoric acid be received in a mercurial apparatus, it will paſs over in the ſtate of gas.

---

* Lead is employed, becauſe this acid diſſolves glaſs and ſiliceous earth. TRANS.

917. For

917. For the firſt knowledge of this acid we are indebted to Margraf; but what he obtained always held ſilex in ſolution, becauſe he employed glaſs or earthen veſſels in the preparation of it. The Duke de Liancourt, under the name of Boulanger, greatly enlarged our knowledge reſpecting the properties of this acid (248 *et ſeq.*) and Scheele ſeems to have completed it; but we are not yet acquainted with the fluoric radical, becauſe it has never yet been poſſible to decompoſe the acid.

918. *Table of the Combinations of the Boracic Acid with the Salifiable Baſes, in the Order of their Affinity for that Acid.*

Lime
Barytes
Magneſia
Potaſh
Soda
Ammonia
Oxide of zinc
Oxide of iron
Oxide of lead
Oxide of tin
Oxide of cobalt
Oxide of copper
Oxide of nickel
Oxide of tellurium
Oxide of mercury
Alumine

All the ſalts formed by the combination of boracic acid, with theſe baſes, are called *Borates.*

919. The *boracic acid,* before known under the name of *Homberg's Sedative Salt*, is a concrete acid extracted from borax, a ſalt brought from India by

by the Dutch. We are very imperfectly acquainted with the origin of this ſalt, as well as with the method of extracting and purifying it. Chemical analyſis has ſhewn that borax is a neutral ſalt with an exceſs of baſe, and that this baſe is ſoda. The acid is ſometimes found in a free ſtate in the water of certain lakes: that of the lake Cherchiaio in Italy contains 94½ grains in a pint.

920. To extract boracic acid from borax, the latter muſt be diſſolved in boiling water; the liquor is then to be filtered while very warm, and ſulphuric acid poured into it: this acid ſeizes on the ſoda, and the boracic acid being ſeparated, becomes free. By cooling, it may be obtained under a cryſtalline form.

921. It is now well known that boracic acid is always the ſame in whatever manner it may be diſengaged, provided it has been purified by waſhing, and by making it once or twice cryſtallize. It is ſoluble in water and alcohol: to the flame of the latter it communicates a green colour. It combines with the ſalifiable ſubſtances, both in the wet and in the dry way: in the latter caſe its affinity for alumine, inſtead of being the leaſt of all, is greater than that which it has for ammonia. The radical of this acid is totally unknown: it has never yet been poſſible to ſeparate from it the oxygen.

922. *Table of Combinations of the Arſenic Acid, with the Salifiable Baſes, in the Order of their Affinity for that Acid.*

Lime
Barytes
Magneſia
Potaſh
Soda
Ammonia
Oxide of zinc
Oxide of manganeſe
Oxide of iron
Oxide of lead
Oxide of tin
Oxide of cobalt
Oxide of copper
Oxide of nickel
Oxide of biſmuth
Oxide of tellurium
Oxide of mercury
Oxide of antimony
Oxide of ſilver
Oxide of gold
Oxide of platina
Alumine

All the ſalts formed by theſe combinations of the *arſenic acid*, are called *Arſeniates.*

923. Macquer, in a memoir publiſhed among thoſe of the academy of ſciences for the year 1746, ſhewed, that by expoſing to a ſtrong heat a mixture of white oxide of arſenic and nitre, he obtained a neutral ſalt, which he called *Neutral Arſenical Salt.* Chemiſts were not then able to comprehend how a metallic ſubſtance could act the part of an acid; but we have been taught by more modern experiments that, in ſuch caſes, the arſenic becomes oxygenated by taking oxygen from the nitric acid, and that by theſe means it becomes a real acid (714).

924. The proceſs for obtaining arſenic acid, and diſengaging it from every combination, is now well known.

known. The ſimpleſt method is to diſſolve white oxide of arſenic in three times its weight of muriatic acid; to add to the ſolution, while ſtill in a ſtate of ebullition, a quantity of nitric acid, equal to double the weight of the arſenic oxide, and then to evaporate the mixture to dryneſs. The oxygen of the nitric acid unites with and acidifies the oxide of arſenic; the nitric radical paſſes off in gas, and the muriatic acid is converted into gas alſo. To get rid of all the foreign acid that may remain, the concrete arſenic acid muſt be calcined till it begins to become red; and what is left in the crucible will be pure arſenic acid.

925. The proceſs of Scheele, repeated at Dijon by Morveau, conſiſts in diſtilling the muriatic acid from off mangangeſe, and receiving the oxygenated muriatic gas thence formed, in a receiver containing white oxide of arſenic covered with a little diſtilled water. The white oxide takes from the muriatic acid its ſuperabundant oxygen, and by theſe means is converted into arſenic acid, while the oxygenated muriate becomes common muriatic acid. Theſe two acids muſt then be ſeparated by diſtilling them in a gentle heat, which ought to be increaſed towards the end of the operation. The muriatic acid paſſes over, and the arſenic acid remains white and under a concrete form. By this proceſs the arſenic acid is often mixed with a little white oxide of arſenic, which has not been ſufficiently oxygenated;

but this does not take place when nitric acid is employed.

926. According to theſe obſervations, the arſenic acid may be defined: a white concrete metallic acid, formed by the combination of arſenic with oxygen, fixed in the fire, even at that degree which brings it to a red heat, which diſſolves in water, and is ſuſceptible of combining with ſeveral ſalifiable baſes.

927. *Table of the Combinations of the Tungſtic Acid with the Salifiable Baſes.*

The order of the affinities of this acid is not known; we know only that it can combine with four earths, three alkalies, and ſixteen metallic oxides, which are,

Lime
Magneſia
Barytes
Alumine
Potaſh
Soda
Ammonia
Oxide of gold
Oxide of ſilver
Oxide of platina
Oxide of copper
Oxide of iron
Oxide of tin
Oxide of lead
Oxide of mercury
Oxide of biſmuth
Oxide of cobalt
Oxide of nickel
Oxide of zinc
Oxide of antimony
Oxide of arſenic
Oxide of manganeſe
Oxide of molybdena

All the ſalts formed by the tungſtic acid, with the ſalifiable baſes, are called *Tungſtates*.

928. The

928. The *tungſtic acid* is extracted from a metal called Tungſten (727) the ore of which has often been confounded with that of tin. The cryſtallization of this ore has ſome reſemblance to that of the garnet (521); its ſpecific gravity is ſix times that of water, and its colour varies from a pearly white to reddiſh, and to yellow. The ſpecific gravity of its regulus is greater than that of the ore; for it is nearly equal to ſeven times that of water (796). Tungſten-ore is found in ſeveral parts of Saxony and Bohemia. Wolfram alſo is an ore of tungſten, and is frequently found in the tin mines of Cornwall *. Tungſten in both theſe ores is in the ſtate of an oxide: it even appears that in thoſe of Saxony and Bohemia it is more than oxidated: it performs in them the part of an acid, and is united with lime.

929. To obtain tungſtic acid in a free ſtate, mix one part of tungſten-ore with four parts of the carbonate of potaſh, and fuſe the mixture in a crucible of platina. When the matter has cooled, reduce it to powder, and pour over it twelve parts of boiling water; then add nitric acid, which will unite with the potaſh, and diſengage the tungſtic acid. This acid will be immediately precipitated under a concrete form. More nitric acid may be added, which muſt be evaporated to dryneſs; and you may continue in this manner till no more red vapours are diſengaged.

---

* It is of a browniſh black colour. TRANS.

diſengaged. You may then reſt aſſured that the tungſtic acid is completely oxygenated.

930. *Table of the Combinations of the Molybdic Acid with the Salifiable Baſes.*

The molybdic acid is one of thoſe, for the diſcovery of which we are indebted to Scheele. The order of its affinities for the different ſalifiable baſes is not known: we know only that it can combine with four earths, three alkalies, and fifteen metallic oxides, which are,

Lime
Magneſia
Barytes
Alumine
Potaſh
Soda
Ammonia
Oxide of gold
Oxide of ſilver
Oxide of platina
Oxide of copper
Oxide of iron
Oxide of tin
Oxide of lead
Oxide of mercury
Oxide of biſmuth
Oxide of cobalt
Oxide of nickel
Oxide of zinc
Oxide of antimony
Oxide of arſenic
Oxide of manganeſe

931. Molybdic acid is molybdena oxygenated (733); for this ſemi-metal is ſuſceptible of oxygenation to ſuch a degree, as to become a concrete acid. To obtain it in this form, put into a retort one part of the ore of molybdena, as preſented by Nature, which is a real ſulphuret of molybdena, and add to it five or ſix parts of nitric acid, diluted with a fourth of water, and proceed to diſtillation. The oxygen of the nitric acid then uniting itſelf to the molybdena and the ſulphur, will transform the firſt into

oxide of molybdena, and the latter into ſulphuric acid. More nitric acid muſt be added in the ſame proportion four or five times. When no more red vapours appear, the molybdena is oxygenated and acidified, and will be found at the bottom of the retort in a pulverulent form, and white like chalk. As this acid is very little ſoluble, it may, without great danger of much loſs, be waſhed in warm water, in order to free it from the ſulphuric acid which may have remained adhering to it. By this proceſs you will obtain molybdic acid exceedingly pure.

The ſalts formed by molybdic acid, with the different baſes, are called *Molybdates.*

932. *Table of the Combinations of the Chromic Acid with the Salifiable Baſes, in the Order of their Affinity for that Acid.*

Barytes
Lime
Strontian
Potaſh
Soda
Ammonia

The order of the affinity of the metallic oxides for chromic acid is unknown.

The ſalts formed by the chromic acid, with the different baſes, are called *Chromates.*

933. The *chromic acid* was found by Vauquelin, completely formed, in that ſubſtance known under the name of the Red Lead-Ore of Siberia (759). The radical of this acid is an unknown ſubſtance, to which Vauquelin gave the name of Chrome. To obtain the acid pure and diſengaged from every other ſubſtance, firſt boil, in forty parts of water, one part of the red lead-ore, finely pulverized, and two parts carbonate of ammonia. The two acids, in this mixture, change baſes; the carbonic acid forms with the lead a carbonate of lead, which is precipitated; and the chromic acid forms with the alkali a chromic ſalt, which remains diſſolved in the water: nothing then is neceſſary but to add to the ſolution an acid capable of ſeizing on the ammonia, and the chromic acid will remain pure.

934. *Table of the Combinations of the Acetous and Acetic Acid with the Salifiable Baſes, in the Order of their Affinity for theſe Acids.*

Barytes
Potaſh
Soda
Lime
Magneſia
Ammonia
Oxide of zinc
Oxide of manganeſe
Oxide of iron
Oxide of lead
Oxide of tin
Oxide of cobalt
Oxide of copper
Oxide of nickel
Oxide of tellurium
Oxide of arſenic
Oxide of biſmuth
Oxide of mercury
Oxide of antimony
Oxide of ſilver
Oxide of gold
Oxide of platina
Alumine

All the ſalts, formed by the above acids, are called *Acetites* or *Acetates*. The old chemiſts were

acquainted

acquainted with none of theſe ſalts, except the following, viz. acetite of potaſh, acetite of ſoda, acetite of ammonia, acetite of lead, and acetite of copper. For the diſcovery of that of arſenic, we are indebted to Cadet *. The properties of the other acetites were made known chiefly by Wenzel, the academicians of Dijon, and by Laſſone and Prouſt.

935. The acetous radical is carbon and hydrogen: the addition of oxygen will form acetous acid. The ſame principles form the tartareous, oxalic, citric, malic, &c. acids; but the proportions of the above principles are different in theſe bodies; and it appears that the *acetous acid* is the moſt oxygenated of all: it is very probable that it contains alſo a little azote.

936. To produce *acetous acid* or *vinegar*, wine is expoſed to a gentle heat with a fermenting ſubſtance, which is the dregs of vinegar. The ſpirituous part of the wine combines with the oxygen of the air; and on this account, the caſk employed for the proceſs ought never to be more than half full. This acid is exceedingly volatile: it is diluted with a great deal of water, and mixed with foreign ſubſtances. To obtain it very pure, it muſt be diſtilled at a gentle heat in veſſels of earthenware; or it ought rather to be expoſed to cold of about twelve or fourteen degrees below freezing.

---

* See Memoires des Savans Etrangers, vol. iii.

The aqueous part will freeze, and the acid remain liquid.

937. To obtain *acetic acid*, take acetite of potaſh, or of copper, and pour over it a third of its weight of concentrated ſulphuric acid; then diſtil the mixture, and the reſult will be highly concentrated vinegar, which is *acetic acid*, or *radical vinegar.*

938. The combination of *acetous acid* with the ſalifiable baſes, is eaſily effected; but the greater part of the ſalts which thence reſult, are not cryſtallizable. This eſtabliſhes a difference between them and the ſalts formed by the tartareous and oxalic acids; which, in general, are very little ſoluble.

939. *Table of the Combinations of the Malic Acid with the Salifiable Baſes.*

With the order of the affinities of this acid for the ſalifiable baſes, we are not acquainted; we know only that it can combine with four earths, three alkalies, and fifteen metallic oxides, which are,

Lime
Magneſia
Barytes
Alumine
Potaſh
Soda
Ammonia
Oxide of gold
Oxide of ſilver
Oxide of platina
Oxide of copper
Oxide of iron
Oxide of tin
Oxide of lead
Oxide of mercury
Oxide of biſmuth
Oxide of cobalt
Oxide of nickel
Oxide of zinc
Oxide of antimony
Oxide of arſenic
Oxide of mangancſe.

The

The ſalts formed by the malic acid, are called *Malates*.

940. The malic acid exiſts completely formed in the juice of apples, ripe or unripe; and even in that of ſeveral other fruits. To obtain it alone, the juice of apples muſt be ſaturated with potaſh, or ſoda, and acetite of lead or ſal ſaturni, diſſolved in water, muſt be poured over the ſaturated liquor. In this caſe an exchange of baſes takes place: the acetous acid combines with the potaſh, or the ſoda, and the malic acid, combining with the lead, is precipitated. This precipitated ſalt, which is almoſt inſoluble, being then waſhed, diluted ſulphuric acid muſt be poured over it: the latter expels the malic acid, and ſeizing on the lead, forms with it a ſulphate very little ſoluble, which may be ſeparated by filtration. The malic acid then remains free and in a liquid ſtate.

941. In many fruits the malic acid is found mixed with the citric and tartareous acids. It is nearly in a mean ſtate between the acetous and the oxalic acid: it is leſs oxygenated than the acetous, but more ſo than the oxalic. It differs alſo from the acetous acid by the nature of its radical, which contains a little more carbon, and leſs hydrogen than that of the acetous acid.

942 *Table of the Combinations of the Oxalic Acid, with the Salifiable Baſes, in the Order of their Affinity for that Acid.*

Lime
Barytes
Magneſia
Potaſh
Soda
Ammonia
Alumine
Oxide of zinc
Oxide of iron
Oxide of manganeſe
Oxide of cobalt
Oxide of nickel
Oxide of lead
Oxide of copper
Oxide of biſmuth
Oxide of antimony
Oxide of tellurium
Oxide of arſenic
Oxide of mercury
Oxide of ſilver
Oxide of gold
Oxide of platina.

The ſalts formed by the oxalic acid, are called *Oxalates.*

943. The oxalic acid exiſts completely formed in the juice of ſorrel: it is extracted from that plant, by expreſſing the juice, in which cryſtals of the acid are formed by long reſt. In this ſtate, the oxalic acid is in part ſaturated by potaſh, ſo that it is a neutral ſalt, with a great exceſs of acid.

To obtain the oxalic acid very pure, an artificial proceſs muſt be employed: it may be accompliſhed by oxygenating ſugar, which appears to be the real oxalic radical. For this purpoſe, pour from ſix to eight parts nitric acid over one part of ſugar, and expoſe it to a gentle heat; a ſlight efferveſcence will take place, and a great deal of nitrous gas will

be

be diſengaged. By means of reſt, cryſtals, which are very pure oxalic acid, will then be formed in the liquor. Theſe cryſtals muſt be dried on blotting paper to ſeparate from them any remains of the nitric acid, or it will be better to diſſolve them in diſtilled water, and to cauſe them to cryſtallize a ſecond time.

945. The ſugar can alſo furniſh other acids: the liquor which produced cryſtals of oxalic acid, contains alſo malic acid, ſomewhat more oxygenated than the oxalic acid: by oxygenating the ſugar ſtill more, it will be converted into acetous acid. Scheele firſt diſcovered that the oxalic acid contains potaſh completely formed; and he ſhewed the identity of this acid with that formed by the oxygenation of ſugar.

946. *Table of the Combinations of the Citric Acid with the Salifiable Baſes, in the Order of their Affinity for that Acid.*

Barytes
Lime
Magneſia
Potaſh
Soda
Ammonia
Oxide of mangaheſe
Oxide of iron
Oxide of lead
Oxide of cobalt
Oxide of copper
Oxide of tellurium
Oxide of arſenic
Oxide of mercury
Oxide of antimony
Oxide of ſilver
Oxide of gold
Oxide of platina
Alumine.

Theſe ſalts formed by the citric acid with the ſalifiable baſes, are called *Citrates.*

947. The citric acid is extracted by expreſſion from lemons; in the juice of which it exiſts completely formed. To obtain it pure and concentrated, it muſt be ſuffered to depoſit its mucous part by long reſt, in a cool place; and it muſt then be concentrated by expoſure to cold of nine or ten degrees. The water freezes, and the acid remains liquid. Too great a degree of cold would be prejudicial, becauſe the acid would be engaged in the ice, from which it would be difficult to ſeparate it.

948. Citric acid may be obtained in a ſtill ſimpler manner, by ſaturating lemon-juice with lime: the reſult will be a citrate of lime, ſoluble in water. The ſalt muſt then be waſhed, and ſulphuric acid be poured over it: the latter ſeizing on the lime, forms with it ſulphate of lime, a ſalt almoſt inſoluble, and the *citric acid* remains free in the liquor.

949. *Table of the Combinations of the Tartareous Acid with the Salifiable Baſes, in the Order of their Affinity for that Acid.*

Lime
Barytes
Magneſia
Potaſh
Soda
Ammonia
Alumine
Oxide of zinc
Oxide of iron
Oxide of mangane∫e
Oxide of cobalt
Oxide of nickel
Oxide of lead
Oxide of tin
Oxide of copper
Oxide of biſmuth
Oxide of antimony
Oxide of tellurium
Oxide of arſenic
Oxide of ſilver
Oxide of mercury
Oxide of gold
Oxide of platina.

The

The ſalts formed by the tartareous acid with theſe baſes, are called *Tartrites.*

950. The tartar found adhering to caſks in which wine has been fermented, is a ſalt compoſed of a peculiar acid, combined with potaſh; but in ſuch a manner, that the acid is in conſiderable exceſs. This ſalt is known under the name of *Acidulous Tartrite of Potaſh*; and the acid which enters into its compoſition is the *tartareous acid.*

951. For the means of obtaining *tartareous acid* in a ſtate of purity, we are indebted to Scheele. As this acid has more affinity for lime than for potaſh, purified tartar, according to his preſcription, muſt be diſſolved in boiling water, and lime muſt be added till the whole acid is ſaturated with it. The tartrite of lime formed, is a ſalt almoſt inſoluble; it therefore falls to the bottom of the liquor, eſpecially when it has cooled: the liquor is then to be decanted; and after the ſalt has been waſhed in cold water, it muſt be dried. Sulphuric acid, diluted with eight or nine times its weight of water, muſt then be poured over it, and it muſt be digeſted for twelve hours in a gentle heat, care being taken to ſtir it from time to time. The ſulphuric acid ſeizes on the lime, and forms with it a ſulphate of lime; and the tartareous acid remains free in the liquor. At the end of twelve hours the liquor muſt be decanted; the ſulphate of lime muſt then

then be waſhed in cold water, to take from it the portion of the tartareous acid adhering to it; and the water it has been waſhed with muſt be added to the firſt liquor. If it be afterwards filtrated, you will obtain, by evaporation, *concrete tartareous acid.* About two pounds of purified tartar will furniſh nearly eleven ounces of acid; and to ſeparate this acid from the lime will require about nine ounces of concentrated ſulphuric acid.

952. The carbono-hydrous radical which forms the baſe of this acid (887) appears to be leſs oxygenated in the tartareous acid than in the oxalic acid (945). Some experiments of Haſſenfratz ſeem to prove that azote alſo enters into this radical, and even in a conſiderable quantity. By oxygenating tartareous acid more and more, it may be converted into oxalic, malic, and, at laſt, into acetous acid. It is probable that the difference between theſe acids ariſes not only from the degree of oxygenation, but alſo from the proportion of hydrogen and carbon.

953. The tartareous acid, by combining with the fixed alkalies, is ſuſceptible of two degrees of ſaturation; the firſt conſtitutes it a ſalt with exceſs of acid, known under the name of *Cream of Tartar*, and which is *acidulous tartrite of potaſh.* The ſecond degree of ſaturation gives a ſalt perfectly neutral, known under the name of Vegetable Salt, and which

which is called ſimply *Tartrite of Potaſh.* The tartareous acid, combined with ſoda to ſaturation, produces *tartrite of ſoda*, known under the name of *Seignette's Salt*, or *Sal Polycheſt of Rochelle.*

954. *Table of the Combinations of the Pyro-Tartareous Acid, with the Salifiable Baſes, in the Order of their Affinity for that Acid.*

Potaſh
Soda
Barytes
Lime
Magneſia
Ammonia
Alumine
Oxide of zinc
Oxide of manganeſe
Oxide of iron
Oxide of lead
Oxide of tin
Oxide of cobalt
Oxide of copper
Oxide of nickel
Oxide of tellurium
Oxide of arſenic
Oxide of biſmuth
Oxide of mercury
Oxide of antimony
Oxide of ſilver.

The ſalts formed by the pyro-tartareous acid with theſe baſes, are called *Pyro-tartrites.*

955. The pyro-tartareous acid is an empyreumatic acid very little concentrated, which is extracted by diſtillation from purified tartar. To obtain it, half fill a glaſs-retort with acidulous tartrite of potaſh reduced to powder, and adapt to the retort a tubulated receiver, to which muſt be joined a bent tube, conveyed under a bell placed on a pneumatic apparatus. By graduating the fire, the reſult will be an empyreumatic acid mixed with oil, which is the pyro-tartareous acid. It muſt be ſeparated from the oil

by means of a funnel. During the diſtillation a great deal of carbonic acid gas is diſengaged.

956. This pyro-tartareous acid always contains oil. It is not ſafe to rectify this acid. The academicians of Dijon have ſhewn that the operation is dangerous, and that it is attended with an exploſion.

957. *Table of the Combinations of the Pyro-mucous Acid with the Salifiable Baſes, in the Order of their Affinity for that Acid.*

Potaſh
Soda
Barytes
Lime
Magneſia
Ammonia
Alumine
Oxide of zinc
Oxide of manganeſe
Oxide of iron
Oxide of lead
Oxide of tin
Oxide of cobalt
Oxide of copper
Oxide of nickel
Oxide of tellurium
Oxide of arſenic
Oxide of biſmuth
Oxide of antimony

The ſalts formed by the pyro-mucous acid with theſe baſes, are called *Pyro-mucites.*

958. The pyro-mucous acid is extracted by diſtillation from ſugar, and all ſaccharine bodies. As theſe ſubſtances ſwell up conſiderably in the fire, $\frac{7}{8}$ of the retort into which they are put to be diſtilled, muſt be left empty. This acid is compoſed chiefly of water, and a ſmall portion of oil, ſlightly oxygenated.

Its

Its colour is yellow, inclining to red; if it be rectified by a ſecond diſtillation, it may be obtained leſs coloured. When it falls on the ſkin it ſtains it yellow; and theſe ſtains do not diſappear till the epidermis is removed. The ſimpleſt method of concentrating this acid, is to expoſe it to a cold of ten or twelve degrees below freezing. If oxygen be added to it by means of nitric acid, it may be converted partly into oxalic, and partly into malic acid.

959. *A Table of the Combinations of the Pyro-ligneous Acid with the Salifiable Baſes, in the Order of their Affinity for that Acid.*

Lime
Barytes
Potaſh
Soda
Magneſia
Ammonia
Oxide of zinc
Oxide of manganeſe
Oxide of iron
Oxide of lead
Oxide of tin
Oxide of cobalt
Oxide of copper
Oxide of nickel
Oxide of tellurium
Oxide of arſenic
Oxide of biſmuth
Oxide of mercury
Oxide of antimony
Oxide of ſilver
Oxide of gold
Oxide of platina
Alumine

All the acids formed by the pyro-ligneous acid with theſe baſes, are called *Pyro-lignites*.

960. Moſt kinds of wood, and particularly thoſe which are heavy and compact, when diſtilled by an open fire, give a peculiar acid; but the nature of

it was never examined by any one before Goettling. The reſult of his obſervations on this ſubject may be found in Crell's Chemical Journal for the year 1779. This acid, which has been diſtinguiſhed by the name of the Pyro-ligneous, is of a brown colour, and is highly charged with oil and charcoal. To obtain it pure, it muſt be rectified by a ſecond diſtillation. It appears to be nearly of the ſame nature from whatever wood extracted. Its radical is compoſed chiefly of hydrogen and carbon. Its affinity for the ſalifiable baſes, which we have here indicated, was determined by Guiton-Morveau and Eloi Bourſier, of Clervaux.

961. *Table of the Combinations of the Benzoic Acid, with the Salifiable Baſes.*

With the order of the affinity of this acid for the ſalifiable baſes, we are unacquainted; we know only that it can combine with four earths, three alkalies, and fifteen metallic oxides, which are,

Lime
Magneſia
Barytes
Alumine
Potaſh
Soda
Ammonia
Oxide of ſilver
Oxide of copper
Oxide of iron
Oxide of tin
Oxide of lead
Oxide of mercury
Oxide of biſmuth
Oxide of cobalt
Oxide of nickel
Oxide of zinc
Oxide of antimony
Oxide of arſenic
Oxide of manganeſe
Oxide of tungſten
Oxide of molybdena

The ſalts formed by the benzoic acid with the ſalifiable baſes, are called *Benzoates*.

962. The benzoic acid, which exiſts completely formed in benjamin, was known to the old chemiſts under the name of *Flowers of Benjamin*, and was obtained by ſublimation; but Geoffroy diſcovered that they might be obtained alſo in the humid way. After a great number of experiments made on benjamin, Scheele adopted the following proceſs:— Take good lime-water, holding an exceſs of lime, and digeſt it, portion by portion, over benjamin reduced to fine powder, continually ſtirring the mixture. When it has been digeſted half an hour, decant the liquor; then add a new quantity of lime-water, and repeat this part of the proceſs ſeveral times, till the lime-water ceaſes to be neutralized. Collect all the liquors, and concentrate them by evaporation: when they are reduced as much as poſſible without being cryſtallized, ſuffer them to cool, and then add, drop by drop, muriatic acid, which ſeizing on the lime, there will be formed a precipitate conſiſting of *concrete benzoic acid*.

963. *Table of the Combinations of the Camphoric Acid with the Salifiable Baſes.*

With the order of the affinity of this acid for the ſalifiable baſes, we are unacquainted ; we know only that it can combine with four earths, three alkalies, and fifteen metallic oxides, which are,

Lime
Magneſia
Barytes
Alumine
Potaſh
Soda
Ammonia
Oxide of gold
Oxide of ſilver
Oxide of platina
Oxide of copper
Oxide of iron
Oxide of tin
Oxide of lead
Oxide of mercury
Oxide of biſmuth
Oxide of cobalt
Oxide of nickel
Oxide of zinc
Oxide of antimony
Oxide of arſenic
Oxide of manganeſe

The ſalts formed by the camphoric acid with theſe baſes, are called *Camphorates.*

964. The camphoric acid is camphor oxygenated to acidity. Camphor is a concrete eſſential oil, extracted by ſublimation from a laurel which grows in China and Japan. Koſegarten diſtilled nitric acid eight times from off camphor, and was able to oxygenate it, and to convert it into an acid ſimilar to the oxalic acid ; but which however, in ſome reſpects, was different from it.

965. Camphor being a carbono-hydrous radical, it is not aſtoniſhing that, by being oxygenated, it

ſhould

ſhould form oxalic, malic, and other vegetable acids, according to the degree of oxygenation. The greater part of the phenomena, obſerved by Koſegarten in the combinations of this acid with the ſalifiable baſes, are obſerved alſo in the combinations of the oxalic and the malic acids. Lavoiſier, therefore, was inclined to conſider the camphoric acid as a mixture of theſe two acids.

966. *Table of the Combinations of the Gallic Acid with the Salifiable Baſes.*

With the order of the affinity of this acid for the ſalifiable baſes, we are not acquainted; we know only that it can combine with four earths, three alkalies, and fifteen metallic oxides, which are,

Lime
Magneſia
Barytes
Alumine
Potaſh
Soda
Ammonia
Oxide of gold
Oxide of ſilver
Oxide of platina
Oxide of copper
Oxide of iron
Oxide of tin
Oxide of lead
Oxide of mercury
Oxide of biſmuth
Oxide of cobalt
Oxide of nickel
Oxide of zinc
Oxide of antimony
Oxide of arſenic
Oxide of manganeſe

The ſalts formed by the gallic acid with the ſalifiable baſes, are called *Gallates.*

967. The gallic acid, called alſo the *Aſtringent Principle*, is extracted from the gall-nut, either by

ſimple infuſion or decoction in water, or by diſtillation in a very gentle heat. Its radical is entirely unknown. The commiſſioners of the academy of Dijon have given a very complete treatiſe on this acid. It is found in a great number of vegetables, ſuch as the oak, willow, iris of the marſhes, raſpberry-buſh, nymphæa, cinchona, the bark and flowers of the pomegranate-tree, and in many other kinds of wood and bark.

968. The gallic acid, though exceedingly weak, reddens tincture of turnſole, and decompoſes the ſulphurets. It unites with all metals which have been previouſly diſſolved by another acid, and precipitates them under different colours: with iron it gives a precipitate of a blue or dark violet colour.

969. *Table of the Combinations of the Succinic Acid with the Salifiable Baſes, in the Order of their Affinity for that Acid.*

Barytes
Lime
Potaſh
Soda
Ammonia
Magneſia
Alumine
Oxide of zinc
Oxide of iron
Oxide of manganeſe
Oxide of cobalt
Oxide of nickel
Oxide of lead
Oxide of tin
Oxide of copper
Oxide of biſmuth
Oxide of antimony
Oxide of tellurium
Oxide of arſenic
Oxide of mercury
Oxide of ſilver
Oxide of gold
Oxide of platina

The ſalts formed by the ſuccinic acid with the ſalifiable baſes, are called *Succinates.*

970. The ſuccinic acid is extracted by diſtillation from that kind of amber, known under the name of *Yellow Amber*. For this purpoſe, it is ſufficient to put the amber into a retort, and to expoſe it to a gentle heat: the ſuccinic acid will be found ſublimated under a concrete form in the neck of the retort. The diſtillation, however, muſt not be carried too far, leſt the oil ſhould paſs over. When the operation is finiſhed the acid muſt be depoſited on blotting-paper, that the moiſture may drain off; after which it muſt be purified by repeated ſolution and cryſtallization. Twenty-four parts of cold water are neceſſary to keep this acid in ſolution; but it is much more ſoluble in warm water. It produces only a faint change on blue vegetable colours. The affinity of the ſuccinic acid for the different ſalifiable baſes, as above indicated (969) was firſt determined by Guiton-Morveau.

971. *Table of the Combinations of the Phoſphorus and Phoſphoric Acids with the Salifiable Baſes, in the Order of their Affinity for theſe Acids.*

Lime
Barytes
Magneſia
Potaſh
Soda
Ammonia
Alumine
Oxide of zinc
Oxide of iron
Oxide of manganeſe
Oxide of cobalt
Oxide of nickel
Oxide of lead
Oxide of tin
Oxide of copper
Oxide of biſmuth
Oxide of antimony
Oxide of tellurium
Oxide of arſenic
Oxide of mercury
Oxide of ſilver
Oxide of gold
Oxide of platina

The ſalts formed by the phoſphorous and the phoſphoric acids with the ſalifiable baſes, are called *Phoſphites*, or *Phoſphates*, according to the acid by which they have been formed: the exiſtence of *metallic phoſphites* is however not yet abſolutely certain.

972. As we have already given (391 *et ſeq.*) a ſhort account of the diſcovery of phoſphorus, with ſome obſervations on the manner in which it exiſts in animals and even ſome vegetables, we ſhall now deſcribe the proceſs for rendering it acid. To obtain phoſphoric acid pure and free from all mixture, phoſphorus muſt be burnt under bell-glaſſes, moiſtened in the inſide with diſtilled water; the phoſphorus then takes from the air in which it burns a quantity of oxygen equal to twice and a half its own weight, and thus forms phoſphoric acid. If the acid be required in a concrete ſtate, the phoſphorus muſt be expoſed to the ſame combuſtion over mercury; the acid, in that caſe, appears under the form of white flakes, which ſtrongly attract the moiſture of the atmoſphere.

973. To obtain the acid merely *phoſphorous*, the phoſphorus is ſuffered to burn very ſlowly in the open air in a funnel, inſerted into a glaſs jar. The phoſphorus combining with the oxygen of the air, becomes acid; and, at the end of ſome days, the whole of it is oxygenated. In proportion as the phoſphorous acid is formed, it ſeizes on a portion of the moiſture of the air, and runs into the flaſk.

This

This acid may be eaſily converted into *phoſphoric acid*, by expoſing it for a long time to the air.

974. As phoſphorus has a great affinity for oxygen, it takes it from the nitric acid, and from the oxygenated muriatic acid; and this furniſhes a ſimple and cheap method of obtaining phoſphoric acid. When concentrated nitric acid is employed, a tubulated retort muſt be half filled with it, and cloſed with a glaſs ſtopper; it muſt then be expoſed to a gentle heat, and ſmall bits of phoſphorus, which will diſſolve with efferveſcence, are to be introduced through the tubulure: during this proceſs nitrous gas will eſcape, under the form of red vapour. You muſt continue, in this mannner, to add phoſphorus till no more of it is diſſolved, and the fire muſt be urged a little ſtronger to expel the laſt portions of the nitric acid: the phoſphoric acid will then be found in the retort, partly under the concrete, and partly under the liquid form.

975. *Combinations of the Formic Acid with the Saliſiable Baſes, in the Order of their Affinity for that Acid.*

Barytes
Potaſh
Soda
Lime
Magneſia
Ammonia
Oxide of zinc
Oxide of manganeſe
Oxide of iron
Oxide of lead
Oxide of tin
Oxide of cobalt
Oxide of copper
Oxide of tellurium
Oxide of nickel
Oxide of biſmuth
Oxide of ſilver
Alumine

The ſalts formed by the formic acid with the ſalifiable baſes, are called *Formiates.*

976. The formic acid was known in the ſeventeenth century. Samuel Fiſher firſt obtained it by diſtilling ants; and his reſearches on this ſubject were continued by Margraff, as may be ſeen in a Memoir which he publiſhed in 1749. Ardwiſſon and Oehrn made experiments alſo on this acid, which are deſcribed in a Diſſertation publiſhed by them at Leipſic in 1777.

977. The formic acid is extracted from a large red ant found in the woods. It may be obtained two ways: by diſtillation and lixiviation.

By Diſtillation. Introduce the ants into a glaſs retort or cucurbite furniſhed with a capital, and proceed to diſtillation at a gentle heat: the acid will then paſs into the receiver. The quantity obtained is equal to about half the weight of the ants.

By Lixiviation. Waſh the ants in cold water; then ſpread them out on a cloth, and pour over them boiling water, which becomes charged with the acid part. If the ants be ſlightly preſſed in the cloth, the acid will be ſtronger.

This acid may be obtained pure, and in a concentrated ſtate by rectification; and the phelgm may be ſeparated from it by congelation.

978. *Table of the Combinations of the Bombic Acid with the Salifiable Baſes.*

With the order of the affinities of this acid for the ſalifiable baſes, we are not acquainted; we know only that it can combine with four earths, three alkalies, and fifteen metallic oxides, which are,

Lime
Magneſia
Barytes
Alumine
Potaſh
Soda
Ammonia
Oxide of gold
Oxide of ſilver
Oxide of platina
Oxide of copper
Oxide of iron
Oxide of tin
Oxide of lead
Oxide of mercury
Oxide of biſmuth
Oxide of cobalt
Oxide of nickel
Oxide of zinc
Oxide of antimony
Oxide of arſenic
Oxide of manganeſe

The ſalts formed by the bombic acid with the ſalifiable baſes, are called *Bombiates*.

979. The bombic acid is that furniſhed by the ſilkworm. When the ſilkworm changes into a chryſalide, its humours ſeem to aſſume a character of acidity; and when it transforms itſelf into a butterfly, it ſuffers to eſcape from it a reddiſh and highly acid liquor, which reddens blue paper. To obtain this acid pure, Chauſſier, member of the academy of Dijon, after ſeveral trials, adopted the following method:—the chryſalides of the ſilkworm are to be infuſed in ſpirit of wine, which will be-

come charged with the acid, without attacking the mucous or gummy parts; the ſpirit of wine muſt then be evaporated, and the bombic acid will remain pretty pure. It is not improbable that ſeveral kinds of inſects might furniſh an acid of the ſame kind. The radical of the bombic acid ſeems to be compoſed of carbon, hydrogen, azote, and perhaps phoſphorus.

980. *A Table of the Combinations of the Sebacic Acid with the Salifiable Baſes, in the Order of their Affinity for that Acid.*

Barytes
Potaſh
Soda
Lime
Magneſia
Ammonia
Alumine
Oxide of zinc
Oxide of mangane̕ſe
Oxide of iron
Oxide of lead
Oxide of tin
Oxide of cobalt
Oxide of copper
Oxide of nickel
Oxide of tellurium
Oxide of arſenic
Oxide of biſmuth
Oxide of mercury
Oxide of antimony
Oxide of ſilver

The ſalts formed by the ſebacic acid with the ſalifiable baſes, are called *Sebates.*

981. The ſebacic acid is extracted from fat. To obtain it, melt tallow in an iron pan, and add to it pounded quicklime, keeping continually ſtirring it. The vapour which riſes from the mixture is exceedingly pungent; and, on that account, the operator muſt avoid inhaling it: towards the end of the operation the fire ought to be increaſed.

The ſebacic acid forms with the lime *ſebate of lime*, a ſalt very little ſoluble. To ſeparate it from the fat parts, to which it adheres, the whole maſs muſt be boiled in a large quantity of water; the ſebate of lime diſſolves, and the tallow, being melted, floats on the ſurface. The fat is then ſkimmed off and the water is evaporated; the ſebate is afterwards calcined in a moderate heat, and being re-diſſolved, is again made to cryſtallize: after this operation the ſebate of lime remains pure. To obtain the acid in a free ſtate, ſulphuric acid is poured over the ſebate, and it is then diſtilled; the ſulphuric acid ſeizes on the lime, and the ſebacic acid paſſes over clear into the receiver.

982. *Table of the Combinations of the Lactic Acid with the Salifiable Baſes.*

With the order of the affinities of this acid for the ſalifiable baſes, we are unacquainted; we know only that it can combine with three earths, three alkalies, and fifteen metallic oxides, which are,

Lime
Barytes
Alumine
Potaſh
Soda
Ammonia
Oxide of gold
Oxide of ſilver
Oxide of platina
Oxide of copper
Oxide of iron
Oxide of tin
Oxide of lead
Oxide of mercury
Oxide of biſmuth
Oxide of cobalt
Oxide of nickel
Oxide of zinc
Oxide of antimony
Oxide of arſenic
Oxide of manganeſe

The

The ſalts formed by the lactic acid with the ſalifiable baſes, are called *Lactates.*

983. The lactic acid is found in whey, where it is united with a little earth. For the accurate knowledge which we have of this acid, we are indebted to Scheele. To obtain it, reduce whey by evaporation to one-fourth of its volume; ſeparate all the caſeous part from it by filtration, and to the liquor add lime, which will combine with the lactic acid; then free it from the lime by the addition of oxalic acid, which, with the lime, will form an inſoluble ſalt: the oxalate of lime may be ſeparated from it by decantation; then evaporate the decanted liquor to the conſiſtence of honey, and add ſpirit of wine, which will diſſolve the acid: then ſeparate the ſugar of milk and other foreign ſubſtances by filtration. To obtain the lactic acid alone, nothing will be neceſſary but to get rid of the ſpirit of wine, either by evaporation or diſtillation. The lactic acid unites with almoſt all the ſalifiable baſes, and forms with them uncryſtallizable ſalts.

984. *Table of the Combinations of the Saccho-lactic Acid with the Salifiable Baſes, in the Order of their Affinity for that Acid.*

Lime
Barytes
Magneſia
Potaſh
Soda
Ammonia
Alumine
Oxide of zinc
Oxide of manganeſe
Oxide of iron
Oxide of lead
Oxide of tin
Oxide of cobalt
Oxide of copper
Oxide of nickel
Oxide of tellurium
Oxide of arſenic
Oxide of biſmuth
Oxide of mercury
Oxide of antimony
Oxide of ſilver

The ſalts formed by the ſaccho-lactic acid with the ſalifiable baſes, are called *Saccholates.*

985. The ſaccho-lactic acid is extracted from ſugar of milk. It has been long known that there may be extracted from whey, by evaporation, a kind of ſugar which has a great reſemblance to that obtained from the ſugar-cane. This ſugar, like that of the cane, is ſuſceptible of being oxygenated different ways, and particularly by its combination with the nitric acid, from which it takes a large portion of its oxygen. For this purpoſe, pour nitric acid ſeveral times ſucceſſively over ſugar of milk, and concentrate the liquor by evaporation; then make it cryſtallize, and by theſe means you will obtain oxalic acid (944); but at the ſame time there is ſeparated a very fine white powder, ſuſcep-

tible of combining with earths, alkalies, and ſometimes metals. To this concrete acid, diſcovered by Scheele, the name of the Saccho-lactic Acid has been given. We are little acquainted with the nature of its action on metals; we know only that it forms with them ſalts which are very little ſoluble. The order of the affinities, as given in the above table (984) is that indicated by Bergmann.

986. *Table of the Combinations of the Lithic Acid with the Salifiable Baſes.*

With the order of the affinities of this acid we are unacquainted; we know only that it can combine with four earths, three alkalies, and fifteen metallic oxides, which are,

Lime
Magneſia
Barytes
Alumine
Potaſh
Soda
Ammonia
Oxide of gold
Oxide of ſilver
Oxide of platina
Oxide of copper
Oxide of iron
Oxide of tin
Oxide of lead
Oxide of mercury
Oxide of biſmuth
Oxide of cobalt
Oxide of nickel
Oxide of zinc
Oxide of antimony
Oxide of arſenic
Oxide of manganeſe

The ſalts formed by the lithic acid with the ſalifiable baſes, are called *Lithiates.*

987. The human calculus, according to the experiments of Bergmann and Scheele, appears to be a kind

a kind of concrete ſalt with an earthy baſe, ſlightly acid, and which requires a great deal of water to diſſolve it; for 1000 parts in weight of boiling water are ſcarcely ſufficient to diſſolve three parts of ſalt, moſt of which again cryſtallizes on cooling. To this concrete acid Guiton-Morveau gave the name of *Lithiaſic Acid*; but it has been ſince called the *Lithic Acid.* The properties of this acid are not yet well known. Lavoiſier ſays that he was induced, for ſeveral reaſons, to believe it to be an acidulous phoſphate of lime.

988. *Table of the Combinations of the Pruſſic Acid with the Salifiable Baſes, in the Order of their Affinity for that Acid.*

Potaſh	Oxide of iron	Oxide of biſmuth
Soda	Oxide of mangaueſe	Oxide of antimony
Ammonia	Oxide of cobalt	Oxide of arſenic
Lime	Oxide of nickel	Oxide of ſilver
Barytes	Oxide of lead	Oxide of mercury
Magneſia	Oxide of tin	Oxide of gold
Oxide of zinc	Oxide of copper	Oxide of platina.

The ſalts formed by the pruſſic acid with the ſalifiable baſes, are called *Pruſſiates.*

989. With the nature of the pruſſic acid we are unacquainted. Its radical is alſo unknown; but, from the experiments of Scheele, and thoſe in par-

ticular

ticular of Berthollet, there is reaſon to think that this radical is compoſed of carbon and azote. All that can be ſaid is, that the pruſſic acid combines with iron, and gives it a blue colour; and this is what is called *Pruſſian Blue.* It is ſuſceptible of combining alſo with almoſt all the metals; but the fixed and volatile alkalies deprive them of the acid in conſequence of their greater affinity for it. If any phoſphoric acid is found in it (972) there is reaſon to believe, from the experiments of Haſſenfratz, that it is only accidental.

990. Though the pruſſic acid unites with alkalies, earths, and metals, in the ſame manner as acids, it poſſeſſes only a part of the properties aſcribed to acids; it is not impoſſible therefore that it may have been improperly conſigned to that claſs.

Diviſion of Bodies.

991. There are two ways of dividing bodies, viz. mechanically and chemically. The firſt conſiſts in trituration, grinding on porphyry, and pulverizing: bodies, by this method, to whatever degree of fineneſs the parts may be reduced, are not decompoſed; each molecula is ſtill what it was before diviſion. The ſecond method conſiſts in ſolution or diſſolution; by which the primitive moleculæ of bodies are divided.

992. In chemiſtry, the terms *ſolution* and *diſſolution* were long confounded. *Solution* is the diviſion of the parts of any ſalt in water; *Diſſolution* is the diviſion of a metal in an acid[*]. Theſe two operations have no reſemblance. In the ſolution of ſalts the ſaline moleculæ are only ſeparated from each other; neither the ſalt nor the water experiences any decompoſition; and both may be recovered in the ſame quantity as that which they formed before the operation. The ſame thing may be ſaid of the ſolution of reſins in alcohol, or other ſpirituous liquors.

993. But in the diſſolution of metals in an acid there is always a decompoſition, either of the acid or of the water: the metal paſſes to the ſtate of oxide, and a gaſeous ſubſtance is diſengaged, ſo that after the diſſolution none of theſe ſubſtances is in the ſame ſtate in which it was before: decompoſition and recompoſition therefore have taken place.

994. In the ſolution of ſalts two effects are commonly combined: ſolution by water, and ſolution by caloric. All ſalts are ſuſceptible of being liquefied by caloric, but not all at the ſame temperature;

[†] As the diſtinction which the author here makes between *ſolution* and *diſſolution* ſeems not yet to have been adopted by the Engliſh chemiſts, it has not been obſerved in the tranſlation: the term *ſolution* has been in general uſed. TRANS.

ſome of them, as the acetites of potaſh and ſoda, liquefy at a very moderate heat; but others, as the ſulphates of lime, potaſh, &c. require the ſtrongeſt degree of heat that can be produced. This liquefaction of ſalts by caloric exhibits the ſame phenomena as the liquefaction of ice: 1ſt, It is effected by a determinate degree of heat for each ſalt; and this degree is conſtant during the liquefaction: 2d, There is an abſorption of caloric at the moment when the ſalt diſſolves, and a diſengagement of caloric when the ſalt becomes fixed. All theſe phenomena generally take place during the tranſition of any body whatever from the concrete to the fluid ſtate, and from the fluid to the concrete.

995. The phenomena of ſolution by caloric are always more or leſs connected with thoſe of ſolution by water. If a ſalt is very little ſoluble in water, and very much ſo by caloric, it will be very little ſoluble in cold water, and very much ſo in warm: of this kind is the nitrate of potaſh or *ſaltpetre*; and, in particular, the oxygenated muriate of potaſh. If a ſalt is very little ſoluble, both in water and in caloric, it will be very little ſoluble in water, either cold or warm: of this kind is the ſulphate of lime or *gypſum*.

996. Such is the general theory of the ſolution of ſalts. It would be a matter of ſome importance to aſcertain the quantity of each ſalt that can be diſſolved

ſolved in a given quantity of water, and at different degrees of temperature; as we ſhould thence be able to diſcover the quantities of water and caloric required for the ſolution of each ſalt; how much is abſorbed at the moment when the ſalt liquefies, and how much is diſengaged when it cryſtallizes. I have begun to make experiments on this ſubject *, but they are ſtill far from being complete. It is known that ſome ſalts diſſolve much ſooner in warm than in cold water; becauſe caloric is always employed in the ſolution of ſalts, and it is ſpeedily furniſhed by warm water.

997. Metals generally diſſolve in acids with efferveſcence. This effervescence is produced by the diſengagement of an aeriform fluid, which may be retained by the ſame means as thoſe employed for extracting gaſes. In this *diſſolution* the metal always combines with the oxygen, either of the acid or of the water, and therefore decompoſition and recompoſition both take place: a decompoſition of the acid or of the water, which loſes its oxygen; and a recompoſition, effected by the combination of oxygen with the metal, which by theſe means is converted into an oxide, conſequently the products are ſubſtances different from thoſe which before exiſted.

---

[*] See my *Principes de Phyſique*, art. 1057.

Cryſtallization of Salts.

998. If a ſalt diſſolved in water and caloric be deprived of a part of the caloric and water; in a word, if it be made to cool and to dry, it cryſtallizes. If the operation be ſlow, and if the liquor be left at reſt, the cryſtallization will be regular; if the operation is rapid, and if the liquor be expoſed to agitation, the cryſtallization will be confuſed.

999. The phenomena which take place in the ſolution of ſalts, are exhibited in their cryſtallization, but in an inverſe order; in their ſolution there is an abſorption of caloric; but in their cryſtallization there is a diſengagement of caloric; and the ſame thing happens in the melting of ice and the congelation of water.

1000. The ſalts which liquefy eaſieſt by caloric, are the nitrate of potaſh or ſaltpetre, the oxygenated muriate of potaſh, the ſulphate of alumine or alum, the ſulphate of ſoda or Glauber's ſalt, &c. To make them cryſtallize, they muſt be deprived not only of their water, but alſo of their caloric. In regard to thoſe which require little caloric for their ſolution; and which, on that account, are nearly as ſoluble in cold as in warm water, it will be ſufficient, to make them cryſtallize, to deprive them of of the water which holds them in ſolution : of this kind are the ſulphate of lime or gypſum, the muriates of ſoda, potaſh, &c.

1001. It is in theſe properties of ſalts that the proceſs for refining ſaltpetre is founded. This ſalt, when it comes from the hands of the manufacturer, is compoſed, 1ſt, Of deliqueſcent ſalts, not ſuſceptible of cryſtallization; ſuch as the nitrate of lime or mother-water of nitre, the muriate of lime or calcareous marine ſalt: 2d, Of ſalts almoſt equally ſoluble hot or cold; ſuch as the muriate of ſoda or marine ſalt, and the muriate of potaſh or febrifuge ſalt of Sylvius: 3d, Of the nitrate of potaſh or ſaltpetre, which is much more ſoluble in warm than in cold water. A quantity of warm water, ſufficient to keep in ſolution the leaſt ſoluble of theſe ſalts, ſuch as the muriates of ſoda and potaſh, even when it has cooled, is poured over them. This water holds in ſolution all the ſaltpetre as long as it is warm; but the caſe is not the ſame when it has cooled; about $\frac{5}{6}$ of the ſaltpetre cryſtallize. This ſaltpetre is a little impregnated with foreign matters; but it may be freed from them by a new ſolution in a ſmall quantity of water warm, and a new cryſtallization. What remains is then evaporated to extract the crude ſaltpetre, which may be purified as the preceding. The proceſs followed in refining ſaltpetre may ſerve as a rule in the purification of other ſalts.

1002. All ſalts cryſtallize, each under a form peculiar to itſelf; and this form even varies in the ſame ſalt, according to circumſtances. The figure of the primitive moleculæ, however, of each ſalt is very conſtant in each ſpecies, and the form of the cryſtals varies only in the manner in which the cryſtals are grouped. Hauy has given ſome excellent papers on this ſubject, which may be found in the Memoirs of the Academy of Sciences; and has publiſhed alſo a diſtinct work on the ſtructure of cryſtals. †

Compoſition and Decompoſition of Animal and Vegetable Matters.

1003. The conſtituent principles of vegetables may be reduced to three, common and eſſential to them all, viz. hydrogen, oxygen, and carbon: without theſe no vegetable could exiſt. There are, however, other ſubſtances which are eſſential only to certain vegetables, ſuch as azote, which is found in the cruciform plants. Of theſe three principles two (viz. hydrogen and oxygen) have a great tendency to unite with caloric, and to be converted into gas. In regard to the carbon, it is fixed, and has very little affinity for caloric.

---

† See a tranſlation of this work, illuſtrated with plates, engraved by Lowry, in the *Phil. Magazine*, vol. I. TRANS.

1004. On the other hand, oxygen, which at the uſual temperature tends, with a force nearly equal, to unite itſelf to hydrogen and carbon, has at a red heat much more affinity for carbon than for hydrogen; conſequently at that degree of heat it abandons the hydrogen, and, uniting with the carbon, forms with it carbonic acid.

1005. However variable theſe affinities may be, in proportion to the temperature, it is certain that they are all nearly in equilibrium at the uſual temperature; and this is the reaſon why we have ſaid (837) that vegetables contain neither water, oil, nor carbonic acid, though they contain the elements of them †: a change in the temperature is ſufficient to derange theſe combinations. If the temperature is a little higher than that of boiling water, the hydrogen and oxygen form water which paſſes over during diſtillation: a portion of the hydrogen and carbon form volatile oil; and another portion of the carbon becoming free and fixed, remains in the retort: but if the fire be urged to a red heat, the water, as well as the oil which may be formed, is decompoſed; the oxygen uniting with the carbon forms carbonic acid; and the hydrogen, becoming free and uniting with caloric, eſcapes under the form of gas.

1006. It is ſeen that this decompoſition of vegetable matters takes place at the above degree, in conſequence

---

† It may be readily conceived that the vegetables are ſuppoſed to be perfectly dry, and to furniſh no oil by expreſſion.

ſequence of a play of double and triple affinities; and that while the oxygen attracts the carbon, to form carbonic acid, the caloric attracts hydrogen, to form hydrogen gas. Theſe phenomena always take place in the diſtillation of all vegetable ſubſtances.

1007. The play of affinities is ſtill more complex in plants which contain azote; ſuch as the cruciform plants, and in thoſe which contain phoſphorus: but as the two laſt ſubſtances exiſt in them only in a very ſmall quantity, they do not occaſion a great change in the products: it appears that the phoſphorus remains combined with the charcoal, which renders it fixed; and the azote unites with the hydrogen to form ammonia.

1008. Animal matters are compoſed nearly of the ſame principles as the cruciform plants; and the diſtillation of them gives the ſame reſults. Theſe principles are hydrogen, oxygen, carbon, azote, and phoſphorus; but as animal matters contain more hydrogen and more azote than vegetable ſubſtances, they furniſh more oil and ammonia.

1009. The ſucceſſive rectification of oils exhibits a very ſingular phenomenon. Every time they are diſtilled a little charcoal remains at the bottom of the retort, and a little water is formed. As this phenomenon takes place at each ſucceſſive diſtillation of the ſame oil, the reſult is, that after a great number of rectifications, eſpecially if the operation has been conducted with a pretty ſtrong degree of heat, and in ſmall veſſels, the whole of the oil is converted into water and charcoal; a weight even greater than that of the oil employed is found: this exceſs of weight is that of the oxygen of the air, which, by combining with the hydrogen of the oil, has formed water.

Fermentation.

1010. The different kinds of fermentation reſult from the decompoſition of animal and vegetable ſubſtances; for in every fermentation decompoſition and recompoſition take place. There are three ſorts of fermentation, viz. the vinous, acetous, and putrid.

1011. *Vinous Fermentation* is that which produces ſpirituous liquors; ſuch as wine, cider, beer, &c. To make wine, the expreſſed juice of grapes is put into a large vat, expoſed to the temperature of at leaſt 55°. Soon after, a rapid fermentation takes place, and goes on ſtill increaſing, ſo that the liquor ſeems to boil up with great violence, as if it were over a ſtrong fire, and a large quantity of carbonic acid is diſengaged. The juice of the grapes, from being ſweet and ſaccharine, is converted into

a vinous

a vinous liquor, which when the fermentation is complete, contains no more ſugar, and from which may be extracted by diſtillation, an inflammable liquor, known in commerce and the arts under the name of *Spirit of Wine*, or *Alcohol.* The production of wine therefore is owing to the fermentation and metamorphoſis of this ſaccharine part.

1012. Let us now examine what gives birth to the carbonic acid diſengaged in this operation, and to the inflammable liquor which is formed; and how a ſweet body, a vegetable oxide, can be thus transformed into two ſubſtances ſo different, one of which is combuſtible, and the other incombuſtible. For this purpoſe we muſt endeavour to acquire an accurate knowledge of the fermentable body, and of the products of fermentation; for nothing is created, either naturally or by art: in every operation there is the ſame quantity of matter, both before it begins, and after it is ended; the quality and the quantity of the principles are the ſame; there are no changes but in the modifications and the new combinations. Let us examine, therefore, what are the conſtituent principles of fermentable bodies; and for that purpoſe let us ſelect *Sugar*, which, among the ſimpleſt of all theſe bodies, is that eaſieſt to be analyzed.

1013. Sugar is a vegetable oxide with two baſes: it is compoſed of hydrogen, carbon, and oxygen. In

100 parts of it there are 8 of hydrogen, 28 of carbon, and 64 of oxygen. To cauſe it to ferment, it muſt be diſſolved in four times its weight of water; but as water and ſugar do not ferment without the addition of ſome other ſubſtance, fermentation muſt be excited by a little yeaſt of beer: when the fermentation is once produced, it will continue of itſelf to the end. I ſhall now give the reſult of an experiment made on a large ſcale by Lavoiſier. This chemiſt diſſolvod 100 pounds of ſugar in 400 pounds of water, and added 10 pounds of the yeaſt of beer in paſte, which made altogether 510 pounds. The yeaſt was compoſed of 2 pounds, 12 ounces, 1 dram, and 28 grains of dry yeaſt; and 7 pounds, 3 ounces, 6 drams, and 44 grains of water.

The conſtituent principles therefore of the materials of this fermentation were,

lib.	oz.	dr.	gr.				lib.	oz.	dr.	gr.
407	3	6	44	of water, compoſed of	Hydrogen	—	61	1	2	71·40
					Oxygen	—	346	2	3	44·60
100				of ſugar, compoſed of	Hydrogen	—	8			
					Oxygen	—	64			
					Carbon	—	28			
2	12	1	28	of dry yeaſt, compoſed of	Hydrogen	—		4	5	9·30
					Oxygen	—	1	10	2	28·76
					Carbon	—		12	4	59·00
					Azote	—			5	2·94
510	0	0	0				510	0	0	0

The quantities of each of theſe conſtituent principles:

		lib.	oz.	dr.	gr.	lib.	oz.	dr.	gr.
Hydrogen of the	water	60	0	0	0	69	6	0	8·70
	water of the yeaſt	1	1	2	71·40				
	ſugar —	8	0	0	0				
	yeaſt —		4	5	9·30				
Oxygen of the	water	340	0	0	0	411	12	6	1·36
	water of the yeaſt	6	2	3	44·60				
	ſugar	64	0	0	0				
	yeaſt —	1	10	2	28·76				
Carbon of the	ſugar —	28	0	0	0	28	12	4	59·00
	yeaſt —		12	4	59				
Azote of the yeaſt	—			5	2·94			5	2.94
						510	0	0	0

1014. The next thing is to examine the products of the fermentation. To aſcertain theſe, Lavoiſier employed the apparatus repreſented *fig.* 45; by means of which he was able to determine the quantity and quality of all the products ſeparately, and to weigh them at any period he choſe. This apparatus conſiſts of a large matraſs A, to which is adapted a braſs cap *a b*, having ſcrewed into it a bent tube *c d*, furniſhed with a cock *e*. To the tube is adapted a kind of glaſs receiver B, with three necks, and below it is placed a bottle C, with which it has a communication. At the end of the receiver B is a glaſs tube *g h i*, cemented at *g* and *i* to braſs collars: this tube is deſtined to contain concrete and

and highly deliqueſcent ſalts, capable of taking up moiſture from the ſubſtances which paſs through it. This tube is followed by two bottles, D and E, filled to *x* and *y* with cauſtic alkali, diſſolved in water. All the parts of this apparatus are united to each other by means of ſcrews that preſs upon collars of oiled leather, to prevent the paſſage of air. Each piece is alſo furniſhed with two cocks, ſo that it can be ſhut at both its extremities; and, by theſe means, each can be weighed ſeparately at every period of the experiment that may be thought neceſſary.

1015. The fermentable matter is put into the matraſs A. In one or two hours after, eſpecially if the temperature of the place where the experiment is performed be about 65° or 70°, the liquor becomes turbid, and begins to foam; bubbles, which burſt at the ſurface ariſe; the number of theſe bubbles increaſes, and there is diſengaged a large quantity of very pure carbonic acid gas, accompanied with foam, which is nothing elſe than the yeaſt that ſeparates itſelf. At the end of ſome days, according to the degree of heat, the diſengagement of gas decreaſes; but it does not ceaſe entirely till a long time after the fermentation is finiſhed.

1016. The 510 pounds of fermentable ſubſtances, furniſhed at firſt 35 pounds, 5 ounces, 4 drams, and 19 grains of dry carbonic acid, which carried with them about 13 pounds, 14 ounces, and 5 drams of water; and there remained in the veſſel a vinous ſlightly acid liquor, at firſt turbid, which, however, afterwards became clear of itſelf, and ſuffered a portion of the yeaſt to be depoſited. The total weight of this liquor was 460 pounds, 11 ounces, 6 drams, and 53 grains.

1017. By analyzing ſeparately all theſe ſubſtances, and reſolving them into their conſtituent parts, the following reſults were obtained, after a very laborious operation:—

1018. *Table of the Reſults obtained by this Fermentation of Sugar.*

lib.	oz.	dr.	gr.			lib.	oz.	dr.	gr.
35	5	4	19	of carbonic acid, compoſed of —	oxygen — — —	25	7	1	34
					carbon — —	9	14	2	57
57	11	1	58	of dry alcohol, compoſed of	oxygen combined with hydrogen	31	6	1	64
					hydrogen combined with oxygen	5	8	5	3
					hydrogen combined with carbon	4	0	5	0
					carbon — —	16	11	5	63
2	8			of dry acetous acid, compoſed of	hydrogen — —		2	4	0
					oxygen — —	1	11	4	0
					carbon — —		10	0	0
4	1	4	3	of ſaccharine reſiduum, compoſed of —	hydrogen — —		5	1	67
					oxygen — —	2	9	7	27
					carbon — —	1	2	2	53
1	6	0	50	of dry yeaſt, compoſed of	hydrogen — —		2	2	41
					oxygen — —		13	1	14
					carbon — —		6	2	30
					azote — —			2	37
408	15	5	14	of water, compoſed of	hydrogen — —	61	5	4	27
					oxygen — —	347	10	0	59
510	0	0	0			510	0	0	0

1019. *Quantities of each of the Conſtituent Principles of theſe Reſults.*

lib. oz. dr. gr.		lib.	oz.	dr.	gr.
409 10 0 54 of oxygen, viz.	In the water	347	10	0	59
	— carbonic acid	25	7	1	34
	— alcohol	31	6	1	64
	— acetous acid	1	11	4	0
	— ſaccharine reſiduum	2	9	7	7
	— yeaſt		13	1	14
71 8 6 66 of hydrogen, viz.	— water	61	4	4	27
	— water of the alcohol	5	8	5	3
	combined with the carbon in the alcohol	4	0	5	0
	In the acetous acid	—	2	4	0
	— ſaccharine reſiduum	—	5	1	67
	— yeaſt		2	2	41
28 12 5 59 of carbon, viz.	— carbonic acid	9	14	2	57
	— alcohol	16	11	5	63
	— acetous acid		10	0	0
	— ſaccharine reſiduum	1	2	2	53
	— yeaſt		6	2	30
Azote 2 37	—			2	37
510 0 0 0		510	0	0	0

1020. In examining theſe reſults (1018) we obſerve that of 100 pounds of ſugar, 4 pounds, 1 ounce, 4 drams, and 3 grains, were not decompoſed: the operation, therefore, was performed only on

lib. oz. dr. gr.
95 14 3 69 of ſugar;

That

That is to ſay, on

lib.	oz.	dr.	gr.	
61	6	0	45	of oxygen,
7	10	6	6	of hydrogen, and
26	13	5	18	of carbon ;

which were ſufficient to form the alcohol, carbonic acid and acetous acid produced by the fermentation. It is not neceſſary, therefore, to ſuppoſe that the water is decompoſed in this operation, unleſs it be pretended that the oxygen and hydrogen exiſt in ſugar in the ſtate of water. It is more probable that the three conſtituent principles of ſugar are in a ſtate of equilibrium with each other, which ſubſiſts till it is deſttoyed either by a change of temperature, or by double affinity ; and it is only then that the principles, combining two and two, form water and carbonic acid. It muſt be obſerved alſo, that the hydrogen and carbon do not exiſt in the alcohol in the ſtate of oil ; they are there combined with a portion of oxygen, which renders them ſuſceptible of mixture with water.

1021. In this fermentation the carbon of the ſugar divides itſelf into two portions, one of which combines with the oxygen, to form carbonic acid ; and the other with the hydrogen and water, to form alcohol ; ſo that if theſe two ſubſtances could be re-combined, ſugar would be re-formed.

1022. *Acetous Fermentation* is the acidification of wine, which takes place in the open air by the abſorption of the oxygen of the atmoſphere: the reſult is *acetous acid*, known under the name of *Vinegar*. It is compoſed of hydrogen and carbon combined together, and carried to the ſtate of acid by oxygen; but the proportions of theſe two principles are not yet well known.

1023. Vinegar being an acid, it was concluded, from analogy, that it contains oxygen; but this fact has been alſo proved by direct experiments. 1ſt, Wine is not converted into vinegar unleſs when in contact with the air. 2d, The volume of the air in which this converſion is effected, becomes diminiſhed, and this diminution is occaſioned by the abſorption of the oxygen gas. 3d, Wine may be converted into vinegar if it be oxygenated by any other means whatever.

1024. This aſſertion is clearly proved by an experiment of Chaptal. Take carbonic acid gas, diſengaged from beer during its fermentation, and ſaturate water with a volume of it equal to its own; place this water in a cellar in veſſels expoſed to the air, and at the end of ſome time the whole will be converted into *acetous acid*. As the carbonic acid gas of the beer holds in ſolution a little alcohol, the water contains all the materials neceſſary for forming acetous acid: the alcohol furniſhes hydrogen and a portion

portion of carbon; the carbonic acid furniſhes carbon and oxygen; and the air furniſhes the oxygen wanting to carry the mixture to the ſtate of acetous acid.

1025. It is here ſeen that nothing is neceſſary but to add hydrogen to carbonic acid, in order to conſtitute *acetous acid*, or, in general, *vegetable acid*; and, on the other hand, that we need only deprive vegetable acids of their hydrogen, to convert them into carbonic acid. This operation, as may readily be perceived, is much ſimpler than has hitherto been ſuppoſed.

1026. *Putrid Fermentation* is a total decompoſition of ſubſtances which putrefy. In this fermentation, as in the vinous, the phenomena are effected, in conſequence of affinities very complex. The conſtituent principles here ceaſe as effectually to be in equilibrium, as in the vinous fermentation; but the reſults of the combinations are very different from thoſe given by the latter. To diſcover theſe reſults, the apparatus, fig. 45, uſed for dermining thoſe of vinous fermentation (1014) may be employed. In the latter, the hydrogen remains united with a portion of water and carbon, to form alcohol (1019); in putrid fermentation, all the hydrogen is diſſipated under the form of hydrogen gas, while the oxygen and the carbon eſcape in carbonic acid gas; and nothing remains but a vegetable earth, mixed with a little carbon and iron.

1027. The putrefaction of vegetables, therefore, is a complete analyſis of theſe ſubſtances; in the courſe of which, all the principles are diſengaged under the form of gas, except the earth, which forms what is called *Mould*. Such are the reſults when the ſubſtance contains only oxygen, hydrogen, carbon, and a little earth; and even theſe ſubſtances, when alone, ferment badly and with difficulty: a conſiderable time is required for the putrefaction to be complete.

1028. The caſe, however, is not the ſame when the ſubſtance contains *azote*, as ſeveral vegetable and all animal matters do. Azote tends greatly to promote putrefaction: when azote is preſent it is much ſpeedier, and for this reaſon, when it is neceſſary to haſten putrefaction, vegetable and animal matters are mixed together; in this mixture conſiſts the whole art of making manure. The introduction of azote not only accelerates the phenomena but forms ammonia by combining with hydrogen (376, 380). If the azote be firſt ſeparated from theſe ſubſtances, no more ammonia will be formed; for azote is eſſential to its compoſition, as has been proved by Berthollet (238).

1029. We ſhall ſhew hereafter, that combuſtible bodies are almoſt all ſuſceptible of combining with each other. Hydrogen gas poſſeſſes this property in an eminent degree; it diſſolves carbon, ſulphur, and phoſphorus; and this gives riſe to three of its varieties (301, 308, 312). The two firſt have a peculiar and very diſagreeable odour; that of ſulphurated hydrogen gas (301) appproaches near to that of rotten eggs; that of phoſphorized hydrogen gas (308) reſembles the ſmell of putrid fiſh; and that of ammonia is equally penetrating and diſagreeable. It is the combination of theſe odours which produces that exceedingly fœtid ſmell, exhaled from animal matters in a ſtate of putrefaction. Sometimes that of ammonia is the prevailing odour, which may be eaſily known by its affecting the eyes; ſometimes it is that of ſulphur, or rotten eggs, as is the caſe with fecal matters; and ſometimes that of phoſphorus, which is ſimilar to that of putrid herrings.

1030. It ſometimes happens that the courſe of putrid fermentation is deranged by ſome particular cauſes. Fourcroy and Thouret obſerved ſome peculiar phenomena in regard to dead bodies buried at a certain depth in the burying-ground of the ci-devant Innocens, and ſecured, in a certain degree, from the contact of the air. They remarked, that the muſcular part was converted into animal fat: this was owing to the azote of theſe matters being diſengaged by ſome particular cauſe; ſo that nothing remained but hydrogen and carbon, matters proper for producing fat. Animal dejections are compoſed chiefly of carbon and hydrogen; they approach therefore to the ſtate of oil; and indeed, they furniſh that ſubſtance by diſtillation with an open fire; but the ſmell of it is inſupportable.

1031. We know, in general, that animal matters are compoſed of hydrogen, carbon, and azote, and often with the addition of ſulphur and phoſphorus; the whole carried to the ſtate of an oxide, by a greater or leſs quantity of oxygen: but with the proportions of theſe principles we are abſolutely unacquainted. It is to be hoped, however, that future obſervations will complete this part of chemical analyſis.

Of the Phyſical Properties of Fire.

1032. What is vulgarly called *Fire*, is nothing elſe than a burning body, the parts of which become diſunited, and evaporate into ſmoke, flame, &c. In the eyes of a philoſopher, this combuſtion is the effect of a cauſe which long eluded our reſearches, but of which it can now be ſaid, that we have a much better knowledge than we ever had before.

1033. It is univerſally agreed, that what cauſes combuſtion is a real matter, which however muſt be excited before it can exerciſe its action; and as this matter is capable of affording light, and as what gives light is capable of burning, it is reaſonable to think that fire and light are the ſame ſubſtances, but differently modified. As the principle of of combuſtion, this matter is called *Caloric*; and, as the principle of light, it is called *Light.*[*]

1034. We ſhall firſt conſider this matter as the cauſe of heat and combuſtion, and examine, 1ſt, Its nature: 2d, What are the means of exciting its action: 3d, In what manner this action is propagated: 4th, What are its effects on bodies: 5th, What are the means of increaſing its action, of diminiſhing it, or of deſtroying it entirely.

Of the Nature of Fire.

1035. The principle of fire is a very ſubtile, highly rare, and exceedingly elaſtic body, deſtitute of gravity, diſperſed throughout the whole univerſe; which when in a ſtate of freedom, tends to put itſelf everywhere in equilibrium; and which has been ſucceſſively known by the names of *Inflammable Principle*, *Principle of Heat*, *Matter of Heat*, *Matter of Fire*, and by the moderns called *Caloric.*

1036. This fluid penetrates and pervades all bodies, even the hardeſt; it combines with ſeveral of them (359); and it tends to diffuſe itſelf in an uniform manner. When alone, it is ſufficient to heat bodies; but in that ſtate it is not ſufficient to burn them: to produce this effect, it muſt be aſſiſted by

---

[*] By ſome the Latin term *Lumen* is preferred. TRANS.

another fluid, which is pure air; but even the concurrence of theſe two fluids would be inſufficient, were not their action excited by ſome artificial means.

1037. The matter of fire is fixed and unalterable. It is ſo fluid, that it never ceaſes to be in that ſtate, unleſs it combines with certain bodies. It is even the chief cauſe of the fluidity of bodies: it is by its action that their parts ſeparate from each other, loſe their adheſion, and acquire that reſpective mobility in which their fluidity conſiſts. On the other hand, it is by the decreaſe of its action, or by its abſence, that the parts approach each other, adhere together, and reſume the conſiſtence they before poſſeſſed. It may even be ſaid, that the matter of heat is the only ſubſtance fluid *per ſe*; and that if a ſubſtance of this kind did not counteract the general tendency which all the parts of matter have towards each other, they would all unite ſo as to form one ſolid.

1038. The matter of fire is capable of attacking the hardeſt bodies: nothing can reſiſt it; and yet it reſiſts every thing. It may be conſidered as an univerſal ſolvent; and this forms an eſſential diſtinction between it and all other ſubſtances.

1039. The matter of fire is everywhere preſent; it penetrates all bodies; it exiſts in the earth which we inhabit, in the air we breathe, in the food with which we are nouriſhed, and even in ourſelves; and though it is capable of conſuming every thing, as its action is never ſufficiently ſtrong to produce combuſtion (1036) inſtead of hurting us, it contributes to preſerve our exiſtence. It forms a part of the fluid which we breathe (89); and it is almoſt the only portion of that fluid which ſerves to maintain life (98).

1040. The matter of fire or *caloric* can exiſt in bodies in two different ſtates: in that of combination, and that of freedom (16): in the former, caloric excites no heat ſenſible to our organs; but in the ſtate of freedom, it excites heat which is ſtronger in proportion as it is more abundant.

1041. At an equal temperature, different bodies do not contain, under the ſame volume, an equal quantity of combined caloric; and in this reſpect there are differences between them, beſides that of their denſities. Attempts have been made to meaſure the quantity of caloric which the different kinds of bodies are capable of containing; and on this ſubject Lavoiſier and Laplace made ſeveral ingenious experiments.* To have a proper conception of them, it muſt be obſerved, that when the caloric combined in a body is rendered free, it produces a ſtronger degree of ſenſible heat in propor-

---

* Memoires de l'Acad. des Sciences 1780, p. 355.

tion as the quantity diſengaged is greater. It is this quantity of caloric, combined in a body, that is called *Specific Caloric.* To meaſure it, the body muſt be put into a veſſel deſtined for that purpoſe, *fig.* 46, and which we ſhall deſcribe hereafter. This veſſel muſt be placed within another filled with ice, and be ſecured from the heat of the atmoſphere by a third veſſel containing ice alſo. The caloric diſengaged from the body ſubjected to experiment, cauſes a part of the ice in the ſecond veſſel to melt, by combining with it, and conſequently without adding any thing to its temperature (1040): this portion of melted ice flows into a veſſel F, placed below the inſtrument. As the quantity of caloric which ought to combine with ice, in order to cauſe it to melt, and to keep water in the liquid ſtate is known, the quantity of ice melted, will therefore denote the quantity of caloric diſengaged from the body ſubjected to experiment; which will determine its *ſpecific caloric.*

1042. It reſults from what has been ſaid (1041) that during the tranſition of a body from the ſolid to the fluid ſtate, a deal of caloric is abſorbed by its combination with that body; and hence the reaſon why at the time of a thaw the cold is ſtill very ſenſible. The ſame thing takes place during the tranſition from the fluid ſtate to that of vapour; and it is on this account that, when any ſubſtance evaporates from the ſurface of a body, it always cools it.

it. On the other hand, during the paſſage of a body from the ſtate of vapour to that of fluid, there is always a diſengagement of caloric, accompanied with heat; and the caſe is the ſame during the tranſition of a body from the fluid to the ſolid ſtate.

1043. In any combination or change of ſtate, therefore, if there be a diminution of ſenſible heat, that heat will re-appear entire when the ſubſtances return to their former ſtate; and reciprocally in the change of ſtates, if there be an augmentation of ſenſible heat, this new heat will diſappear when the ſubſtances return to their primitive ſtate. This principle is confirmed by the experiments of Lavoiſier and Laplace, by whom it has been generalized and extended in the following manner, to all the phenomena of heat: *All the variations of heat, either real or apparent, experienced by a ſyſtem of bodies in a ſtate of change, are reproduced in an inverſe order, when the ſyſtem returns to its former ſtate.*

Of the Means by which the Action of Heat may be increaſed.

1044. There are three principal ways of exciting the action of heat: theſe ways are, 1ſt, By the eliſion or friction of ſolid bodies; 2d, Fermentation and efferveſcence; 3d, By concentrating the ſolar rays.

1045. *Firſt way.* The eliſion or friction of ſolid bodies, is the method moſt frequently employed to excite the action of fire: it is ſo common that every one is acquainted with it. It is well known that fire may be kindled by ſtriking a piece of ſteel againſt a hard ſtone; and it is known alſo, that a body which is ſtruck, or rubbed, becomes hot, and ſometimes to ſuch a degree, as to ſparkle or inflame. We have inſtances of this in the ſhodding of wheels, which ſtrikes fire from the pavement; in axle-trees, which take fire by the friction they experience againſt the nave of the wheel; and theſe effects are greater according as the duration of the ſhocks or friction is more conſiderable, and according as the bodies ſubjected to them are harder or more tenacious; for a plate of ſteel may be made red hot by repeated ſtrokes on an anvil, which would never be the caſe with a piece of lead.

1046. *Second way.* Fermentation and effervefcence produce heat, which ſometimes proceeds to inflammation. If an acid be poured into an alkali, it excites an effervefcence, which produces ſenſible heat. If ſulphuric acid, well dephlegmated, be mixed with water, it produces a very ſtrong heat, which heats the veſſel to ſuch a degree, that the hand can no longer be kept on it. If an acid highly concentrated, ſuch as nitric acid well dephlegmated, be poured upon oil, the fermentation is ſometimes ſo ſtrong, that it immediately inflames. All theſe effects are produced in conſequence of the friction occaſioned by the mutual penetration of the two ſubſtances into the pores of each other, which rouſes the free caloric lodged in them. Hence ariſes the heat which is perceived; and if it be very great, a combination with the oxygen of the air takes place, and the reſult is inflammation.

1047. *Third way.* The ſolar rays heat bodies expoſed to them. Theſe rays are certainly compoſed of the matter of fire, excited and put in action by the ſun (1033). This matter inſinuates itſelf between the particles of bodies, and adds to the quantity they before contained; and hence the heat which is perceived.

1048. This degree of heat is always much inferior to that neceſſary for combuſtion; but theſe rays, by being concentrated, are capable of fuſing or burning fuſible or combuſtible bodies on which they are thrown: this effect may be produced different ways. Theſe rays may be collected in great number on a very ſmall ſpace by a lens or a concave mirror; and by theſe means a very ſtrong heat, capable of fuſing or burning bodies, may be excited *.

---

* See my *Principes de Phyſique*, art. 1252 *et ſeq.* and art. 1355 *et ſeq.*

Of the Manner in which the Action of Fire is propagated.

1049. The action of fire in bodies is propagated two ways: 1ſt, It excites in them only a ſlight inteſtine motion, which produces an augmentation of heat that dilates the heated body, and increaſes its volume. The body, by means of the heat communicated to it, becomes then hotter and larger than it was before. Such is the caſe with a cold body placed near one that is hot: 2d, This action of fire agitates ſo much the matter of the body expoſed to it, that it diſunites its moleculæ, and often diſſipates them in flame and in ſmoke, as is the caſe with a bit of wood placed on burning coals.

1050. In the firſt caſe, where there is only a communication of heat, every thing ſeems to take place according to known laws: the heat acquired by a body, is loſt by that which communicates it: the firſt becomes hotter than it was, and the other leſs hot; and this variation continues till the two bodies have acquired an equal temperature. In the ſame manner, a body to which a certain quantity of motion has been communicated, gradually loſes it, in proportion as it communicates it to other bodies.

1051. The ſecond caſe, however, that where the heat is carried to inflammation, is different: the action of the heat is then propagated with increaſing force; its effects always become greater in proportion as it acts on a larger quantity of matter. In a word, a ſpark becomes a conflagration. To have a proper conception of the reaſon of this ſingular phenomenon, the reader muſt recollect what has been already ſaid (46) that caloric, when in combination with any body, gives no ſenſible heat; but the heat becomes ſtronger and its effects more rapid, according as the quantity of caloric rendered free is greater. What is it then that furniſhes this large quantity of free caloric during the combuſtion of bodies?

1052. Bodies cannot burn except when in contact with pure air, or oxygen gas (100) becauſe combuſtion conſiſts in the combination of the baſe of that air called *Oxygen*, with the combuſtible body (92); but pure air contains a great quantity of caloric combined with its baſe (89). When its oxygen then combines with the burning body, its caloric aſſumes the free ſtate, and unites itſelf to that which occaſioned the commencement of the combuſtion; for it is neceſſary that the combuſtion ſhould be begun by ſome of the means already indicated (1044 *et ſeq.*) hence there reſults an augmentation of heat, and this augmentation diſpoſes a greater number of the particles of the combuſtible body

body to combine with the oxygen furniſhed to it by the air which is renewed; for if the air were not renewed, the combuſtion would ceaſe (100). This new oxygen, by combining with the combuſtible body, abandons in like manner its caloric, which, becoming free, eſcapes with its well known characters, that is to ſay, heat, light, and flame; and the greater the quantity of oxygen thus combined and fixed in a given time, the greater will be that of the caloric rendered at once free, and conſequently the more rapid and violent will be the conflagration. It may now be eaſily ſeen why the progreſs of inflammation goes on always with increaſing force.

1053. Combuſtion then is the decompoſition of pure air or oxygen gas, effected by a combuſtible body. For this purpoſe oxygen muſt have a greater affinity for that body than it has for caloric: but this affinity takes place only at a certain degree of temperature, which is even different for each combuſtible ſubſtance: on this account we have ſaid (1052) that it is neceſſary that the combuſtion ſhould be begun by ſome one of the means above indicated (1044 *et ſeq.*). In this caſe the oxygen, which forms the baſe of pure air, is abſorbed, while caloric and light become free and are diſengaged.

1054. During every combuſtion oxygenation takes place; but it is not eſſentially neceſſary that in every oxygenation there ſhould be combuſtion, ſince combuſtion, properly ſo called, cannot be effected without a diſengagement of light and caloric.

1055. The preſent ſtate of nature is a ſtate of equilibrium, to which it could not attain till all the ſpontaneous combuſtions poſſible, at our common temperature, had taken place. There can be no new combuſtions, therefore, till this ſtate of equilibrium be deſtroyed, and the combuſtible ſubſtances have attained to a higher temperature. Let us illuſtrate this fact by a ſuppoſition.

1056. If the common temperature of the earth ſhould become higher than it is at preſent, for example, equal to that of boiling water, as phoſphorus is combuſtible at a much leſs degree, it would no longer exiſt in the ſtate of pure and ſimple phoſphorus, but would always preſent itſelf under the form of an acid; that is to ſay, as much oxygenated as it is poſſible for it to be, and its radical would be among the number of the unknown ſubſtances; becauſe it could not be obtained alone and ſeparated from its oxygen. The caſe would be ſucceſſively the ſame with all combuſtible bodies, if the temperature of the earth ſhould be raiſed higher than it is at preſent, and a temperature would at length take place, at which all combuſtions would be entirely exhauſted; at which no combuſtible bodies could exiſt; at which they would all be oxygenated as much as they could be; at which they would all be incapable of combining with new oxygen, and conſequently would all be incombuſtible.

1057. There can, therefore, be no bodies combuſtible to us but thoſe which are incombuſtible at our temperature; conſequently, to render them combuſtible, their temperature muſt be raiſed. When they have attained to the neceſſary temperature, combuſtion commences; and the caloric, diſengaged by the decompoſition of the pure air or oxygen gas, maintains the temperature neceſſary for continuing it. If the caloric diſengaged is not ſufficient for that purpoſe, the combuſtion ceaſes.

1058. In compound diſtillation (1083) as well as in combuſtion, there is a ſeparation of a part of the principles of the body ſubjected to it, and a combination of the ſame principles in another order: but in combuſtion, ſomething more takes place: there is an addition of a new principle which is *oxygen*, and the diſſipation of another principle, which is *caloric*.

1059. The neceſſity of employing oxygen in a ſtate of gas, and of accurately determining the quantities, renders it very difficult to make correct experiments in regard to combuſtion. What ſtill increaſes the difficulty is, that the products furniſhed by the combuſtion are almoſt always diſengaged

gaged in the ſtate of gas; and it is exceedingly difficult to retain them all: great precaution and particular kinds of apparatus are neceſſary for that purpoſe.

1060. During every combuſtion, therefore, pure air or oxygen is decompoſed; caloric is diſengaged and rendered free, and heat is produced; but a heat of greater or leſs ſtrength, according to the nature of the burning body; for, according to the experiments of Lavoiſier and Laplace*, one ounce of charcoal in burning conſumes 4037½ cubic inches of pure air, and forms about 3021·1 cubic inches of carbonic acid gas. This ounce of charcoal conſumes, therefore, 3 ounces, 4 drams, 2¾ grains of pure air (94) and forms 3 ounces, 5 drams, and 11,6645 grains of carbonic acid gas (222); from which it follows, that an ounce of charcoal furniſhes 1 dram, 8·9145 grains of carbon, or a little leſs than ⅐ of its weight. But as the combination of pure air or oxygen with carbon forms here a new elaſtic fluid, by combining with a portion of caloric, little heat is produced; whereas the heat diſengaged from pure air, when its baſe combines with inflamed phoſphorus, is nearly 2⅕ times as great as when this pure air is converted into carbonic acid gas; for in the firſt of theſe caſes this heat can diſſolve 4 pounds, 4 ounces, and about 5 drams of

---

[*] Memoires de l'Acad. des Sciences, 1780, p. 397.

ice; and in the ſecond it can diſſolve only 29 ounces, 4 drams.

1061. Combuſtible bodies, therefore, are thoſe which have more affinity for oxygen than oxygen has for caloric; and the greater this affinity, or the tendency of theſe bodies to combine with oxygen, the more combuſtible are the bodies. It is not then, as before believed, caloric already combined with theſe bodies that renders them combuſtible; it is even very probable that the greater part of the moſt combuſtible bodies, ſuch as ſulphur and phoſphorus, contain very little or none of it.

1062. Lavoiſier and Laplace make, on this ſubject, the following important reflection *: Almoſt all bodies can exiſt in three different ſtates, either under the ſolid form, the liquid form, that is to ſay, fuſed, or under the form of elaſtic fluid: theſe three ſtates depend only on the greater or leſs quantity of caloric which pervades theſe bodies, or with which they are combined. Fluidity and elaſticity prove that caloric is preſent in abundance; while ſolidity and compactneſs prove its abſence. As it is proved that aeriform ſubſtances contain a large quantity of combined caloric, it is probable that ſolid bodies contain very little.

---

[*] Memoires de l'Academie des Sciences, 1777, p. 598.

Specific Caloric of Bodies.

1063. We have already ſaid (1041) that, at equal temperatures, different bodies do not contain under the ſame volume an equal quantity of combined caloric; and that it is this quantity of combined caloric which has been called the *Specific Caloric* of bodies. To meaſure it, Lavoiſier and Laplace made uſe of an apparatus (*fig.* 46) to which they gave the name of *Calorimeter.* This apparatus conſiſts of a veſſel having three diviſions, viz. an interior *f f f f f f* (*fig.* 47, which repreſents a vertical ſection of the veſſel) a middle one *b b b b b*, and an external one *a a a a a a.* The internal diviſion is formed of iron-wire L M (*fig.* 48) and may be cloſed by means of a cover G H: in this diviſion the body ſubjected to experiment is placed. *Fig.* 49 repreſents a tranſverſal ſection of the calorimeter; and the interior diviſion is ſeen at *f f f f.* The middle diviſion *b b b b* (*fig.* 47 and 49) is deſtined for containing the ice which muſt be placed round the internal diviſion, and which is to be melted by the caloric diſengaged from the body ſubjected to experiment. This ice is ſupported by a grate *m m* (*fig.* 47 *and* 50) below which is a ſtrainer *n n* (*fig.* 51). In proportion as the ice is diſſolved by the caloric diſengaged from the body placed in the interior diviſion, the water flows

through

through the grate and the ſtrainer, and running down the cone *c c d* (*fig.* 47) and the tube *x y* is collected in the veſſel F, placed below to receive it (*fig.* 46): *u* is a cock (*fig.* 47) by means of which the flowing of the water from the middle diviſion may be ſtopped at pleaſure. In the laſt place, the exterior diviſion *a a a a a a* (*fig.* 47 *and* 49) is for receiving the ice, deſtined to prevent the effect of the external heat on the ice of the middle diviſion. The water produced by the melting of the ice in the exterior diviſion, runs through the tube S T (*fig.* 47) which may be opened or ſhut by the cock *r*. During the experiment the calorimeter is cloſed by the cover F F (*fig.* 52) which has its edges elevated that it may contain ice, intended to perform the ſame office as that in the interior diviſion. With this apparatus the quantity of caloric diſengaged from a body which cools, or from a living body, or that even diſengaged during the combuſtion of any ſubſtance, may be eaſily determined. Theſe experiments ought to be made only during cool weather; at a time when the temperature of the external air is about 39 or 40 degrees above zero.

1064. If it were required to meaſure the *ſpecific caloric* of a ſolid body, its temperature ought to be raiſed, for example, to 212 degrees; it muſt then be put into the calorimeter, and ſuffered to remain there till its temperature be reduced to 32°. By then weighing the water which has flowed into the veſſel F *(fig.* 46*)* the quantity of ice diſſolved during the cooling may be determined. To have a known term of compariſon, it muſt be obſerved, that 1 pound of water at 167 degrees of heat, will diſſolve a pound of ice (332). To determine the ſpecific caloric of the body, the quantity of ice diſſolved muſt be divided by the weight of the body, expreſſed in parts of a pound, multiplied by the number of degrees which its temperature has been raiſed above 32° : the quotient will indicate the quantity of ice which a pound of that body can diſſolve in cooling 1 degree of F. If this quotient be then multiplied by 167, the product will be the quantity of ice which a pound of that body, heated to 167 degrees, can diſſolve in cooling to 32°. This will be the value of its *ſpecific caloric.* Another method may be employed, which will give exactly the ſame reſult. If we ſuppoſe, as above, that the temperature of the ſolid body has been raiſed to 212 degrees, we ſhall have the following proportion: As 212 degrees, the temperature of the ſolid, is to the quantity of ice diſſolved, ſo is 167 degrees to *x*. This term *x*, divided by the weight of the ſolid, will indicate how much caloric each pound of the ſolid can furniſh, or what quantity of ice it can diſſolve; and this will be the value of its *ſpecific caloric.*

1065. If the body, the *ſpecific caloric* of which is required, be a fluid, it muſt be put into ſome veſſel, the ſpecific caloric of which has been previouſly

viouſly determined. The proceſs is the ſame as that above deſcribed (1064); but care muſt be taken to deduct from the quantity of ice diſſolved, that which ariſes from the cooling of the veſſel.

1066. If the quantity of caloric which diſengages itſelf from the combination of ſeveral ſubſtances be required, they muſt be all reduced to the temperature of 32°; they are then to be mixed together in the interior part of the calorimeter, and to be left there till they return to the term of 32°. The quantity of ice diſſolved will indicate the quantity of caloric diſengaged during the combination.

1067. When bodies in a ſtate of combuſtion, or living bodies, are ſubjected to trial, the operation is the ſame, except that freſh air muſt be introduced into the calorimeter; that this air when it arrives ſhall be at the temperature of 32°; and that it be at the ſame when it iſſues from it, in order to avoid error in the reſult: for this purpoſe, when it enters and iſſues from the veſſel, it muſt be made to paſs through tubes ſurrounded with pounded ice.

1068. *Table of the Specific Caloric of Bodies, as found by different Chemiſts.*

BY LAVOISIER AND LAPLACE.

Water	100000
Mercury	2900
Sheet iron	10999
Cryſtal	19290
Quicklime	21689
Sulphuric acid	33460
Nitric acid	66139

BY CRAWFORD.

Water	1·0000
Cows milk	·9990
Wheat	·4770
Barley	·4210
Oats	·4160
Rice	·5060
Peaſe	·4920
Horſe beans	·5020
Fruit of the pine-tree	·5000
Charcoal	·2631
Aſhes of do.	·0909
Aſhes of elm-wood	.1402
Cinders	·1923
Aſhes of pit-coal	·1855
Pit-coal	.2771
Copper	.1111

Braſs — —	·1123
Iron — —	·1269
Ruſt of iron —	·2500
Lead — —	·0352
Yellow oxide of lead —	·0680
Tin — —	·0704
White oxide of tin —	·0990
Zinc — —	·0943
Antimony —	·0645
Waſhed diaphoretic antimony	·2272
Atmoſpheric air —	1·7900
Vital air —	4·7490
Azotic gas —	·7936
Carbonic acid gas —	1·0454
Hydrogen gas —	21·4000

1069. Lavoiſier and Laplace, after ſome very accurate experiments, determined the quantity of caloric diſengaged during the combuſtion of phoſphorus, hydrogen gas, and carbon, by the quantity of ice which each of theſe ſubſtances during its combuſtion was able to diſſolve; and this denotes the degrees of heat which each is capable of exciting.

1070. The combuſtion of phoſphorus furniſhes a concrete acid, in which it is propable there remains little combined caloric: this combuſtion, therefore, affords a method of determining very nearly the quantity of combined caloric contained in oxygen gas.

gas. By the combuſtion of one pound of phoſphorus, there is employed and abſorbed, 1½ pound of oxygen, and there are formed 2½ pounds of concrete phoſphoric acid; the caloric, diſengaged during this combuſtion and furniſhed by the oxygen gas, cauſes 100 pounds of ice to diſſolve, and conſequently excites 13532 degrees of heat. To form one pound of oxygen gas, requires 18432 cubic inches, or 10⅔ cubic feet; for each cubic foot weighs ½ grain (98): one pound therefore, or 10⅔ cubic feet of oxygen gas, can furniſh a quantity of caloric capable of exciting 9032 degrees of heat, and of diſſolving 66⅔ pounds of ice. Hence it reſults, that one cubic foot of oxygen gas can furniſh a quantity of caloric, capable of exciting above 876 degrees of heat, and of diſſolving 6 pounds 4 ounces of ice.

1071. The combuſtion of one pound of hydrogen gas cauſes to diſſolve 295 pounds, 9 ounces, 3 drams, and 36 grains of ice. To make one pound of hydrogen gas, requires 249081 cubic inches, or 144 cubic feet, and 249 cubic inches; ſince each cubic inch weighs only 37 thouſandth parts of a grain (293). To burn this quantity of hydrogen gas, 5 pounds, 10 ounces, 5 drams, and 24 grains of oxygen gas are employed and abſorbed. To form this weight of oxygen gas, 104448 cubic inches, or 60 cubic feet, and 768 cubic inches, are neceſſary. The reſult of this combuſtion is 61440 grains,

grains, or 6 pounds, 10 ounces, 5 drams, and 24 grains of water. The 5 pounds, 10 ounces, 5 drams, and 24 grains of oxygen gas, abſorbed during the experiment, could furniſh a quantity of caloric capable of exciting 51031·9 degrees of heat, which could diſſolve 377 pounds, 12 ounces, 3 drams, 40 grains of ice. There were employed, however, only 39936·5789 degrees of heat, which diſſolved 295 pounds, 9 ounces, 3 drams, and 36 grains of ice; conſequently, there remained a quantity of caloric, capable of producing 11095·3541 degrees of heat, which would have diſſolved 82 pounds, 3 ounces, and 4 grains of ice, and which excited no heat. The reaſon of this is, that the oxygen by combining with the hydrogen to form water, retains a portion of its caloric: 1ſt, To keep the water in a ſtate of liquidity: 2d, Becauſe water at the temperature of ice, or even in the ſtate of ice, ſtill contains a great deal of caloric, without reckoning that which it borrows from the hydrogen gas, and of which the quantity is not known. It is aſſerted that a pound of water, at the temperature of ice, ſtill contains enough of caloric to excite about 1665 degrees of heat.

1072. In the combuſtion of one pound of charcoal, there were employed and abſorbed 47396 cubic inches, or 27 cubic feet, 740 cubic inches of oxygen gas, which weighed 23698 grains, or 2 pounds, 9 ounces, 1 dram, 10 grains; and the re-

ſult

ſult was 47358 cubic inches, or 27 cubic feet, 702 cubic inches of carbonic acid gas, which weighed 32914 grains, or 3 pounds, 9 ounces, 1 dram, and 10 grains. The 2 pounds, 9 ounces, 1 dram, and 10 grains of oxygen gas, which were abſorbed during the experiment, could have furniſhed a quantity of caloric capable of exciting 23142·57 degrees of heat, which would have diſſolved 171 pounds, 6 ounces, 6 drams, and 42 grains of ice: the degrees of heat employed, however, were only 13027·5, which diſſolved 96 pounds, 8 ounces of ice; conſequently there remained a quantity of caloric, capable of producing 10115·07 degrees of heat, which could have diſſolved 74 pounds, 14 ounces, 6 drams, and 42 grains of ice; but which excited no heat, becauſe this caloric combined with the carbonic acid formed, in order to reduce it to the ſtate of gas. By what has been here ſaid, it is ſeen that each pound of oxygen gas furniſhes by the combuſtion of charcoal, 1ſt, A quantity of caloric, capable of exciting 5066·311 degrees of heat, which can diſſolve 37 pounds, 8 ounces, 3 drams, and 44 grains of ice: 2d, Another quantity of caloric which combines with the carbonic acid to bring it to the ſtate of gas, and which would excite 3933·6889 degrees of heat, and diſſolve 29 pounds, 2 ounces, 1 dram, and 52 grains of ice. This ſhews that one pound of carbonic acid gas, compoſed of 7 cubic feet, and 1164 cubic inches, contains a quantity of caloric capable of exciting 2832·246 degrees of heat, which could diſſolve 20 pounds, 15 ounces, 5 drams, and 28 grains of ice; and that one cubic foot of carbonic acid gas, contains a quantity of caloric capable of exciting 369·089 degrees of heat, which could diſſolve 2 pounds, 11 ounces, 5 drams, and 68 grains of ice.

Oxidation of Metals.

1073. The *oxidation* of metals is a real combuſtion; for it is a combination of the metal with oxygen (1052). The oxidation of metals therefore is an operation, by which, when long expoſed to a certain degree of heat, they are converted into *oxides*, by abſorbing the oxygen of the air. This combinati ontakes place, becauſe at a certain degree of heat, oxygen has more affinity for metals than for caloric; and when it is effected in oxygen gas alone, the diſengagement of caloric is exceedingly rapid, and is often accompanied with heat and light; which proves that metallic ſubſtances are real combuſtible bodies: we muſt however except gold, ſilver, and platina, which cannot take oxygen from caloric, let the degree of heat be what it may. The other metals become charged with a greater or leſs quantity, until the oxygen is in equilibrium between the force of the caloric that retains, and that of the metal which attracts it. This equilibrium is a general law of nature in all combinations.

1074. In

1074. In every oxidation there is an increaſe of the weight of the oxidated metal. Chemiſts were long at a loſs how to account for this increaſe of weight; and the cauſe was not diſcovered till they began to operate in cloſe veſſels, and in known quantities of air: they were then convinced that the exceſs of weight in oxidated metals, ariſes from the oxygen combined with the metal. Mercury, which when oxidated, may be revived without any addition, is exceedingly proper for proving it; for when revived, it gives up the oxygen which had been combined with it, and loſes the weight it acquired by its oxidation.

1075. Thoſe who are deſirous of extracting the oxygen from theſe oxides, are not equally ſucceſsful with them all. Some do not give it up without the addition of charcoal; and in that caſe the oxygen gas obtained is conſiderably mixed. Mercury furniſhes it without any addition; and it begins to paſs off when the crucible becomes red. According to Berthollet, an obſcure heat is not ſufficient; light he ſays is neceſſary to obtain oxygen gas; which ſeems to prove that light is one of its conſtituent principles.

1076. Oxygen gas may be extracted alſo from black oxide of manganeſe, and from the nitrate of potaſh or ſaltpetre; but a degree of heat almoſt equal at leaſt to that which ſoftens glaſs will be neceſſary; and for this reaſon retorts of earthen-ware or porcelain muſt be employed. The pureſt kind of oxygen gas, however, is that diſengaged from the oxygenated muriate of potaſh by heat alone. This operation may be performed in a glaſs retort; and the gas obtained is perfectly pure; which ſeems to prove, in oppoſition to what Berthollet has ſaid (1075), that light is not eſſential to the formation of oxygen gas.

Combinations of Combuſtible Bodies with each other.

1077. As combuſtible ſubſtances take up oxygen with great avidity, they muſt have a great affinity for each other: and this indeed is proved by obſervation. Almoſt all the metals combine with each other; and the reſult is compounds, called *Alloys.* Theſe ſubſtances are more brittle than the pure metals; eſpecially when the alloyed metals differ greatly in their degree of fuſibility. When iron is alloyed with a very fuſible metal, it often breaks while hot, and rather ſo than when cold; becauſe this fuſible metal fuſes at a gentle heat, which breaks the continuity of the parts. The alloy of mercury with other metals often forms only a paſte called *Amalgam.*

1078. Sulphur, phoſphorus, and charcoal, alſo combine with metals. The firſt of theſe combinations was formerly known by the name of Pyrites:

at

at preſent it is called *Sulphuret*. The ſecond combination, or that of phoſphorus, is called *Phoſphuret*; and the third, or that of charcoal, *Carburet*.

1079. Hydrogen, that ſubſtance ſo highly combuſtible, combines alſo in the ſtate of gas with ſeveral combuſtible ſubſtances: it diſſolves ſulphur, phoſphorus, and carbon, and forms thoſe varieties of hydrogen gas, of which we have already ſpoken (301, 308, 312). It is to the emanation of ſulphurated hydrogen gas that the fœtid odour of animal dejections is principally owing. Phoſphorized hydrogen gas inflames ſpontaneouſly by the mere contact of the air, or rather by the contact of oxygen gas. This phoſphorized hydrogen gas has the ſmell of putrid fiſh; and it is probable that a gas of this kind is exhaled from fiſh in a ſtate of putridity.

1080. Hydrogen which has not been carried to the ſtate of gas by caloric, and which combines with carbon, forms oil, volatile or fixed, according to the proportions of the hydrogen and carbon. If the hydrogen and carbon are mixed in equal proportions, it is volatile; if there be an exceſs of carbon, it is fixed: this exceſs of carbon, when the oil is expoſed to a heat greater than that of boiling water, may be ſeparated from it. Volatile oils, however, are not decompoſed by this degree of heat, but they combine with caloric and form gas; and it is

in

in this ſtate that they paſs over in diſtillation *. A proof that oils are compoſed of hydrogen and carbon is, that the fixed oils, by burning in oxygen gas, are converted into water and carbonic acid; and it is found, that in 100 parts there are 21 of hydrogen and 79 of carbon.

Of Diſtillation.

1081. There are two kinds of diſtillation, ſimple diſtillation and compound diſtillation, We ſhall firſt treat of ſimple diſtillation.

1082. When two ſubſtances are ſubjected to diſtillation, one of which has more affinity for caloric than the other, the object is to ſeparate them. The volatile aſſumes the form of gas; it is then condenſed by cooling in an apparatus proper for that purpoſe: in ſimple diſtillation, therefore, as in evaporation, nothing is decompoſed. In evaporation the object is to collect the fixed product without paying attention to the volatile part; but in diſtillation the contrary is the caſe; the volatile part being that chiefly collected, unleſs it be neceſſary to preſerve both. Simple diſtillation, therefore, is nothing elſe than evaporation in cloſe veſſels; and one is often obliged to loſe a part of the volatile

---

* See a Memoir of Lavoiſier in the *Memoires de l'Acad. des Sciences*, 1784, p. 593.

ſubſtances, eſpecially thoſe which remain conſtantly in the ſtate of gas; and which, if not ſuffered to eſcape, might break the veſſels; ſo that, in this diſtillation, all the products are not known, nor is it poſſible to know them. The ſimpleſt apparatus for this kind of diſtillation, is a retort A (*fig.* 54) to the beak of which D is adapted, and ſecured with luting a receiver E, deſtined to collect and condenſe the products. The retort A is placed in a reverberating furnace M N O P (*fig.* 54) or in a ſand-bath, under a covering of baked clay, as ſeen *fig.* 55. That the vapours which might burſt the veſſel may eſcape, a ſmall hole T (*fig.* 53) is made in the receiver E. On account of the fragility of glaſs, veſſels for diſtillation are made alſo of metal. An apparatus of this kind conſiſts of a cucurbite A (*fig.* 56 *and* 57) of tinned copper; in which may be adjuſted at pleaſure a tin balneum mariæ D (*fig.* 58) with a capital or cover F (*fig.* 56 *and* 57) having attached to it a cooler S S, that the vapours may be condenſed by means of cold water placed around it. When this water becomes hot, it is ſuffered to eſcape by the cock R; and its place is ſupplied by cold water. If the vapours are of a very expanſible nature, and any apprehenſion be entertained that they may not be condenſed ſoon enough, inſtead of receiving them directly from the beak T V of the alembic in the receiver, a worm (*fig.* 59) which conſiſts of a ſpiral pewter tube, is interpoſed between them, and placed in a veſſel of tinned copper B C D E, which is kept full of water that muſt be changed when it becomes hot. In diſtillation, when the condenſed ſubſtance attaches itſelf to the neck of the retort, it is called *Sublimation.* Hence the expreſſions *ſublimation of ſulphur,—ſublimation of the muriate of ammonia,* &c.

1083. In ſimple diſtillation (1082) the ſubſtance diſtilled is firſt reduced to gas by its combination with caloric; but this caloric afterwards depoſits itſelf either in the refrigeratory or in the worm; and the ſubſtance reſumes its ſtate of liquidity. The caſe, however, is not the ſame in compound diſtillation: by this proceſs there is an abſolute decompoſition of the matter ſubjected to diſtillation: one portion, ſuch as the charcoal, remains fixed in the retort, while the whole of the reſt is reduced into gas of different kinds. Some of theſe are ſuſceptible of condenſation by cooling, and of re-appearing under the concrete or liquid form: others remain conſtantly in the aeriform ſtate: ſome of them are capable of being abſorbed by water, others by alkalies; and ſome of them cannot be abſorbed by any ſubſtance whatever. To retain and ſeparate all theſe products, the diſtilling-apparatus, above deſcribed (1078) is not ſufficient: one more complex is required. The following, invented by Lavoiſier, contains every thing neceſſary for the moſt complex diſtillation: A (*fig.* 44) is a glaſs retort, having a tubulure at H, the beak of which B can be adjuſted to a double tubulated balloon G C. To the upper tubulure of this balloon D, is fitted a glaſs tube D E *f*, the extremity of which is conveyed into the liquor contained in the flaſk L. With the flaſk L, which has three tubulures $x\ x\ x$, are connected three other flaſks $L'\ L''\ L'''$, which alſo have each three tubulures $x'x'x'$, $x''x''x''$, $x'''x'''x'''$: each flaſk is connected with the preceding by a glaſs tube $x\ y\ z$, $x'\ y'\ z'$, $x''\ y''\ z''$, and to the third tubulure of the flaſk L''' is adapted a glaſs tube x''' R M, conveyed under a glaſs bell placed on the ſhelf A B C D (*fig.* 6) of a pneumatic tube filled with water. A known weight of diſtilled water is generally put into the firſt flaſk L (*fig.* 44); and into the other three cauſtic potaſh diluted with water. The weight of theſe flaſks, as well as that of the liquors contained in them, muſt be accurately aſcertained and noted down. When every thing is thus arranged, the joinings muſt be well luted. Sometimes there are certain circumſtances which occaſion a re-abſorption of the gas; and, in this caſe, that there may be no danger of the water in the pneumatic tub (*fig.* 6) entering rapidly into the flaſks through the tube x''' R M (*fig.* 44) to one of the tubulures of each flaſk is adapted a capillary tube $s\ t$, $s'\ t'$, $s''\ t''$, $s'''\ t'''$, the extremity of which muſt be immerſed in the liquor of the flaſks. If abſorption takes place, either in the retort or the flaſks, the external air, which fills the vacuum occaſioned by the abſorption, enters through theſe tubes, and no water enters into the flaſks: no inconvenience attends this part of the apparatus, but a ſmall mixture of common air in the products; which, however, makes no material change in the reſults.

1084. When a fire has been made under the retort A (*fig.* 44) and the ſubſtance it contains begins to be decompoſed, the leaſt volatile of the products will be condenſed and ſublimated in the neck of the retort: and it is there chiefly that the concrete ſubſtances may be collected; the moſt volatile matters, ſuch as the light oils, ammonia, &c. will be condenſed in the balloon G C. On the other hand, the gas, which cannot be condenſed by cold, will bubble through the liquors contained in the four flaſks: every thing capable of being abſorbed by the water will remain in the flaſk L: every thing ſuſceptible of being abſorbed by the alkali, will remain in the flaſks L′, L″, L‴; and the gas which cannot be abſorbed neither by the water nor the alkalies, muſt eſcape through the tube x''' R M, at the extremity of which they may be collected in glaſs-bells. In the laſt place, the charcoal and earth being abſolutely fixed, muſt remain in the retort. It will be an evident proof of the correctneſs of theſe reſults, if the weight of all the products be found equal to the weight of every thing put at firſt into the retort.

Of the Effects produced on Bodies by Fire.

1085. The principal effects produced on bodies by fire are, 1ſt, That they are dilated: 2d, That they paſs from the ſolid to the fluid ſtate: 3d, That they are converted into vapour.

1086. *Firſt Effect of Heat on Bodies.* The firſt change which takes place in a body expoſed to the action of the matter of fire or of caloric, is, that its maſs is dilated and its volume augmented. This effect is ſo general, that it may be conſidered as a diſtinguiſhing character of fire or caloric. All bodies therefore are larger during the warm ſeaſons than during the cold: a table either of marble or wood, &c. is larger in ſummer than in winter; this may be eaſily proved by meaſuring it in the two ſeaſons, provided that the inſtrument employed be not of the ſame ſubſtance as the table, for in that caſe it would be ſubject to the ſame increaſe or decreaſe of its dimenſions.

1087. The volume of all bodies is increaſed by heat, but they do not all increaſe in the ſame ratio, nor at the ſame degree. Braſs expands more than ſteel in the proportion of 775 to 474, or of 121 to 74. This difference is employed to correct the effects produced by heat on the balance of time-pieces.

1088. Liquors, when expoſed to heat, expand in the ſame manner as ſolids: thoſe employed for thermometers are a proof of it, for the heat makes the thermometer riſe only in conſequence of its augmenting the volume of the liquor which it contains; but liquids and fluids, in the ſame manner as ſolids, do not all increaſe the ſame quantity at equal degrees of heat: it appears that thoſe which have the leaſt denſity become moſt expanded; hydrogen gas expands more than common air; air more than ſpirit of wine; ſpirit of wine more than oil; linſeed oil more than water; water more than mercury, &c.

1089. *Second Effect of Heat on Bodies.* When dilatation, the firſt effect (1086) has been carried to its utmoſt extent, as the moleculæ of bodies ſtill retain ſome adheſion to each other, if the heat continues to act, the body paſſes to the ſtate of liquefaction or fluidity, more or leſs complete, according to the nature of the heated body, and according to the degree of heat to which it is expoſed. This is the caſe with butter, wax, metals, &c. when expoſed to a ſufficient degree of heat they paſs from the ſolid to the liquid ſtate; or of ſtones, which, when calcined, are reduced to an impalpable powder; and of ſolids, which become fluid.

1090. This effect is more or leſs ſpeedy according to the nature of the bodies which are heated; for they do not all fuſe equally ſoon, nor at the ſame degree of heat: a greater degree is required to melt wax than to melt butter; a ſtill greater is required to fuſe metals; and ſome require more than others. Tin and lead fuſe long before they become red; copper and iron are in a ſtate of ignition long before they fuſe; platina does not fuſe but at a very great degree of heat, and a long time after it has become red.

1091. The action of heat produces a greater effect according as it experiences more reſiſtance, and is more retarded. If the bodies expoſed to it are of ſuch a nature as to yield to its firſt impreſſion, the parts at their ſurface loſe their adheſion, they then liquefy, and even before the others have had time to become hot; thus the maſs fuſes from ſtratum to ſtratum in the ſame manner as butter or wax; or theſe parts are diſſolved in ſmoke and in flame like a billet of wood, which burns at its ſurface while its centre is ſtill almoſt cold. But if the parts at the ſurface have ſufficient fixity, if they reſiſt long enough to give the internal parts time to become hot, the deſtruction of their adheſion muſt everywhere take place nearly at the ſame time, and the fuſion ſoon becomes general. This is what happens to metals when fuſed. Wood burns only progreſſively; and wax and tallow melt only gradually: but metals which at firſt are more difficult to be fuſed, flow more ſpeedily and more completely when they have acquired the degree of heat neceſſary for that purpoſe.

1092. Metals may be rendered more fuſible and at a leſs degree of heat, by alloying them with ſome other ſubſtance. Strong ſolder is an alloy of this nature, which fuſes at a degree of heat leſs than that neceſſary for fuſing the pieces intended to be joined.

1093. *Fuſion* is the ſeparation of the moleculæ of a body: the rupture of their adheſion by the introduction of a large quantity of caloric between their moleculæ. Fuſion in general is performed in crucibles which muſt be capable of ſtanding a great degree of heat: the beſt are thoſe made of very pure argil or porcelain earth. Thoſe brought from Heſſe are pretty good; but thoſe made of a kind of earth found at Limoges, appear to be abſolutely infuſible; and theſe ought to be uſed in preference to all others. The forms uſually given to crucibles are repreſented *fig.* 60, 61, and 62.

1094. Though fuſion may often take place without the body which is expoſed to it being decompoſed, it is one of the means of decompoſition and recompoſition employed in chemiſtry and the arts. It is by fuſion that metals are extracted from their ores, that they are revived, that they are caſt, and that they are alloyed with each other: it is by fuſion alſo

alſo that alkali and ſand are combined together, in order to form glaſs, &c.

1095. In the application of the action of heat to bodies, furnaces of different forms are employed according to the operations for which they are deſtined. A *furnace* is a kind of hollow cylindric tower, A B C D *(fig. 63)*; ſometimes a little wider at the top, with notches *m*, *m*, *m*, to give a paſſage to the air. This furnace ought to have at leaſt two lateral apertures; an upper on E F, which is the door of the fire-hole H I; and a lower one G, which is the door of the aſh-hole C D. In the interval between theſe two doors the furnace is divided into two parts by a horizontal grate, deſtined to ſupport the charcoal. The place occupied by this grate is indicated by the line H I; above the grate is the fire-hole where the fire is maintained; and below it is the aſh-hole, where the aſhes are collected as they are formed.

1096. Another kind of furnace often neceſſary, is that called the *Reverberating Furnace (fig. 54)*: it conſiſts of an aſh-hole H I K L, a fire-hole K L M N, a laboratory M N O P, and a dome R R S S; above the dome is a tube T T V V, to which ſeveral more can be added if required. In the laboratory M N O P is placed the retort A, which is ſupported by two iron bars that run acroſs the furnace; the neck of it paſſes through the lateral aperture

aperture O, and has adapted to it a receiver B. As a ſtrong heat is ſometimes required for this furnace, a large volume of air muſt be made to paſs through it, and in that caſe a great deal of heat is diſengaged. For this reaſon, inſtead of one aperture to the aſh-hole, there muſt be two G, G: when only a moderate heat is required, one of them may be ſhut; if a ſtrong heat be neceſſary, they may be both opened. It will be of advantage alſo to make the upper aperture S S of the dome pretty large. The uſe of the dome is to reverberate the heat and flame on the retort, in order that it may everywhere be expoſed to nearly an equal heat, by which means the vapours can be condenſed only in the beak of the retort and in the receiver; and are alſo forced to proceed thither. When matters which do not require a ſtrong degree of heat are to be fuſed, the reverberating furnace may be employed as a fuſing furnace. The laboratory M N O P in that caſe is removed; and the dome R R S S is placed on the fire-hole M N, as repreſented *fig.* 64.

1097. The beſt *fuſing furnace* ever made, is that conſtructed by Lavoiſier, and which is repreſented *fig* 65. The following is the deſcription which he gives of it in his Elements of Chemiſtry.* "This furnace is in the form of an elliptical ſpheroid A B C D, cut off at the two ends by two planes

---

* Engliſh edition, p. 548.

which paſs perpendicular to the axis through the foci of the ellipſe. From this ſhape it is capable of containing a conſiderable quantity of charcoal, while it leaves ſufficient ſpace in the intervals for the paſſage of the air. That no obſtacle may oppoſe the free acceſs of external air, it is perfectly open below, and ſtands upon an iron tripod. The grate is made of flat bars, ſet on edge, as ſeen *fig.* 66, with conſiderable interſtices between them. To the upper part A B *(fig.* 65*)* is added a chimney, or tube of baked earth, eighteen feet long, and equal in width to nearly half the diameter of the furnace." Lavoiſier recommends, as a thing of importance, to make the tube F G A B as bad a conductor of heat as poſſible; it muſt therefore be conſtructed neither of iron-plate, nor of copper, as is commonly the caſe.

1098. Another kind of furnace is that neceſſary for aſſaying. In this furnace the metal muſt at the ſame time be expoſed to the moſt violent heat, and, ſecured from the contact of the air, become incombuſtible by its paſſage through the coals: on this account it has been called the aſſaying or cupelling-furnace. It is generally of a ſquare form *(fig.* 67*)* and, like the other furnaces, has an aſh-hole A A B B, a fire-hole B B C C, a laboratory C C D D, and a dome D D E E. A ſection of this furnace is ſeen *fig.* 68. The laboratory C C D D *(fig.* 67 *and* 68) is deſtined for receiving the muffle, which is a kind of ſmall oven (*fig*. 69) made of baked earth, and cloſe at the bottom. It reſts on bars which traverſe the furnace (*fig*. 68); and being adjuſted to the door of the laboratory G G, is luted in with clay. It is in this ſmall oven the cupells are placed, and the muffle is ſurrounded with charcoal; that above it being conveyed through the door I of the dome; and that below it, through the door K of the fire-hole. The air which enters through the apertures of the aſh-hole, after having ſerved for the purpoſes of combuſtion, eſcapes through the upper aperture E E of the dome. In regard to the muffle, the air penetrates to it through the door G G, and promotes the oxidation of the metal. This furnace however is attended with the following inconvenience: If the door G G of the laboratory be ſhut, the oxidation, for want of air, takes place ſlowly, while, on the other hand, if it be open, the current of cool air cauſes the metal to become fixed, and retards the operation. To obviate this inconvenience, hot air ſhould be conveyed to the muffle from without, by cauſing it to paſs through an earthen tube, kept in a ſtate of ignition by the furnace itſelf; and thus the interior part of the muffle would never become cold.

1099. *Third effect of heat on bodies.* A ſubſtance liquefied by the action of heat (1089) continues to be heated till the moment when it begins to boil, if it be ſuſceptible of ebullition; after which it acquires no greater heat, however long it may be boiled, but its maſs is at length converted into vapour, and with greater care according as it is leſs compreſſed. Water in vacuo is converted into vapour at a very low degree of heat.

1100. The ebullition of liquors conſiſts in a riſing of a portion of the liquor occaſioned by large bubbles of a very tranſparent fluid; which, proceeding from that part of it moſt expoſed to the heat, traverſes the liquor, and burſts at the ſurface. But of what nature is this fluid? Is it the matter of heat called caloric? It is very certain that liquors do not boil without heat; but it is equally certain that the matter of heat alone is not ſufficient to make them boil, ſince there are ſeveral ſubſtances which never boil, however ſtrongly heated: theſe bubbles therefore muſt be compoſed of ſome other fluid. This fluid is a portion of the liquor reduced to vapours by the violent heat to which it is expoſed, in the ſame manner as a drop of water thrown upon a piece of ignited iron ſpeedily evaporates, forming ſeveral bubbles, which, were they covered with warm water, inſtead of burſting, would immerſe themſelves in the liquor, and cauſe it to riſe. A proof that this fluid is a portion of the liquor reduced to vapour, is, that fuſed metals never boil, becauſe they evaporate only at the ſurface, and becauſe thoſe vapours which tend to riſe cannot traverſe the maſs. It cannot be ſaid that their gravity prevents them from riſing; for mercury, which is the heavieſt of all the metals, except platina and gold, boils like water, becauſe like that fluid, it is reduced into vapour at the bottom, and at the places moſt expoſed to the heat. But thoſe metals which cannot boil when alone, boil with great violence when any ſubſtance capable of furniſhing vapour, ſuch as a piece of wood, is immerſed in them.

1101. Vapours then riſe from any liquor in a ſtate of ebullition; and if the ebullition be continued, all its parts are ſucceſſively evaporated even to dryneſs. It is in this phenomenon that the *third effect produced on bodies by heat* conſiſts, after having made them paſs from the ſolid to the liquid ſtate: it at laſt reduces them into vapour, by making them paſs to the aeriform ſtate. This is what forms the non-permanent elaſtic fluids, of which we have already ſpoken (55).

1102. But if the diſſipation of any ſubſtance is ſudden, if all its parts are evaporated at once, it produces a violent exploſion; becauſe in paſſing to the ſtate of elaſtic fluid, it acquires a prodigious volume in compariſon of that which it had before (346). This is what takes place in the inflammation of gun-powder, as well as in the fulmination of gold (585), and of fulminating ſilver (595). In making theſe experiments, great caution muſt be employed, in order to avoid accident; but eſpecially

ally with fulminating ſilver, which detonates merely by the contact of any body whatever.

Of Detonation.

1103. Oxygen, when it combines with different bodies, does not always diveſt itſelf of all the caloric which conſtituted it a gas: thus, for example, it enters into that combination which forms nitric acid, and into that which forms oxygenated muriatic acid, with the greater part of its caloric; ſo that in nitre, and particularly in the oxygenated muriate, the oxygen to a certain point is in the ſtate of oxygen gas; but condenſed and reduced to the ſmalleſt volume which it can poſſibly occupy. Caloric in its combinations tends then continually to bring back oxygen to the ſtate of gas, ſo that the oxygen adheres very weakly to theſe combinations. The leaſt force is ſufficient to diſengage it, and it often reſumes in a moment the gaſeous ſtate. It is this abrupt tranſition from the concrete to the aeriform ſtate, which has been called *Detonation*, becauſe it is generally accompanied with a loud report.

1104. Theſe detonations are generally produced by the combination of charcoal, either with the oxygenated muriate, or with nitre: however, ſometimes to facilitate the inflammation, ſulphur is added; and this mixture, made according to the proper proportions, conſtitutes gun-powder. Theſe proportions are 76 parts of nitre or ſaltpetre, 12 parts of ſulphur, and 12 parts of charcoal.

1105. The ſudden and inſtantaneous expanſion of theſe gaſes, is not ſufficient to explain all the phenomena reſpecting detonation. This cauſe is not the only one that has an influence in producing them. Carbonic acid gas is formed, and oxygen combines with the combuſtibles. It appears alſo that the caloric diſengaged at the moment of detonation, contributes in no ſmall degree to increaſe the effect. Several reaſons ſeem to prove it.

1106. In the firſt place, though caloric paſſes freely through the pores of all bodies, it can however only paſs ſucceſſively and in a given time: if a large quantity of it therefore is diſengaged at once, and more than can paſs ſuddenly through the pores, it muſt then act in the manner of elaſtic fluids, and overcome every thing that oppoſes its paſſage: a part of this effect muſt take place when gun-powder is fired in a cannon; though the cannon is permeable to caloric, ſo much of it is diſengaged at one time, that it cannot find a paſſage ſufficiently free and ſpeedy through the pores of the metal: it conſequently makes an effort in every direction; and it is this effort which impels the bullet, and makes the cannon recoil.

1107. Secondly, Caloric when become free dilates the gas, which is diſengaged at the moment of the inflammation of the powder ; and this dilatation is greater according as the temperature is more elevated.

1108. Thirdly, It is poſſible that in the inflammation of the powder there is a decompoſition of water, and that it furniſhes oxygen to the charcoal to form carbonic acid. If this be really the caſe, there ought to be formed a large quantity of hydrogen gas, which will contribute to encreaſe the force of the exploſion; for as the cubic foot of hydrogen gas weighs only 63·936 grains, a very ſmall quantity of it is capable of occupying a very large ſpace. It muſt therefore exerciſe a prodigious expanſive force when it paſſes from the liquid to the aeriform ſtate.

1109. Fourthly, The portion of water not decompoſed, muſt in the inflammation of the powder be reduced to vapour ; and it is well known that in the ſtate of gas, water occupies a ſpace 1700 or 1800 times greater than when it is in the liquid ſtate.

1110. From what has been ſaid (1058 *et ſeq.*) it may be eaſily ſeen that theſe three effects of fire on bodies (1086, 1089, 1099) may be reduced to one, viz. that of dilatation; for liquefaction, or fluidity,

dity, is nothing elſe than a greater dilatation than that reſulting from a heat not ſufficient to deſtroy the coheſion of the parts; and vaporization is only dilatation carried to its utmoſt degree.

Of the Means of increaſing the Action of Heat.

1111. There are four ways by which the action of heat, or the effects of the ſame fire maintained with the ſame kind of combuſtible, may be augmented. Theſe ways are, 1ſt, To encreaſe the quantity of matter which ſerves as food to the fire: 2d, To concentrate its action, or to prevent it from extending itſelf, and from being diffuſed over too wide a ſpace: 3d, To direct that action towards the ſame place: 4th, To excite the fire with pure air, or oxygen gas.

1112. *Firſt way.* This method is ſo common, that it ſtands in no need of illuſtration; every body knows, that by adding wood or coals to a fire already kindled, its action will be augmented. The quantity of matter added, however, muſt find a fire proportioned to its volume and degree of inflammability. It would be uſeleſs to add green wood, or wood in a large quantity to a ſmall fire, or a fire of ſtraw; it would only become black; but if the wood is very dry, or divided into ſmall portions or chips, it will ſoon take fire. No body can inflame but by by combining with oxygen (1052); and this combination cannot take place but at a certain degree of heat: if the fire is too weak, or the combuſtible added in too large a quantity, or too much impregnated with water, the fire will be extinguiſhed before the body has had time to become ſufficiently hot. This is the reaſon why a taper is extinguiſhed by inverting it; the melted wax which runs down on the wick, has not acquired the degree of heat neceſſary for its inflammation.

1113. *Second way.* This method is to concentrate the action of the heat, or to prevent it from being extended or diffuſed over too large a ſpace. This effect is what chemiſts produce by means of their furnaces. The fire thus confined becomes, as it were, the centre of a ſphere of action, the radii of which, ſtriking againſt the ſides of the furnace, are reverberated towards the middle, and, their action being there concentrated, act with the more force.

1114. *Third way.* This method conſiſts in directing the action of the fire, or the inflamed particles exhaled from it, towards one place: this is what is done by goldſmiths, jewellers, enamellers, &c. with their lamp and blow-pipe, and their bellows. The flame thus directed is conſiderably lengthened, and becomes ſo active as to fuſe glaſs, enamel, and metals; for the blaſt, eſpecially that of the bellows, introduces into the flame the fluid proper for combuſtion: by theſe means two advantages are obtained; that of exciting a degree of heat, and that of throwing the heat on the part alone required to be heated.

1115. *Fourth way.* This method is that of exciting the fire by pure air or oxygen gas. No degree of heat ſo active as that produced in this manner is known. Lavoiſier, who made a ſeries of very ingenious experiments on this ſubject [*], found no ſubſtance which did not yield to its action. The largeſt burning-glaſſes, ſuch as thoſe of Tehirnhauſen and Trudaine, produced more heat than the porcelain-furnaces; but, beſides the dearneſs and difficulty of procuring ſuch glaſſes, and their want of power to fuſe crude platina, a ſtill greater heat may be obtained by exciting the fire with oxygen gas: as already obſerved, we are acquainted with no degree of heat ſo powerful: by theſe means crude platina may be fuſed on a bit of charcoal.

1116. When matters are to be fuſed which muſt not be brought into contact with charcoal, an enameller's lamp is employed, through the flame of which a current of oxygen gas is made to paſs. The heat is ſomewhat leſs than when the ſubſtance is placed on charcoal; but it is ſtronger than any

---

[†] Memoires de l'Acad. des Sciences, 1782, p. 476 and 1783, p. 566.

other

other degree with which we are acquainted. The ſupports uſed in ſuch caſes are either cupells of bone-aſhes, or ſmall capſules of hard porcelain, or even of metal, which, provided they are not too ſmall, do not fuſe; becauſe metals being good conductors of heat, the caloric is ſpeedily diffuſed throughout the whole maſs, and heats each part leſs.

1117. We have already ſaid (1115) that Lavoiſier made on this ſubject a ſeries of ingenious experiments; the reſults of them are as follow:—

1ſt, Rock-cryſtal, that is to ſay, pure ſiliceous earth, is infuſible; but it becomes ſuſceptible of being ſoftened and fuſed as ſoon as it is mixed.

2d, Lime, magneſia, and barytes, are not fuſible either alone or when combined together: but all theſe ſubſtances, and particularly lime, facilitate the fuſion of all others.

3d, Alumine even alone is completely fuſible; and the reſult is an exceedingly hard, vitreous, and opake ſubſtance, which ſcratches glaſs in the ſame manner as the precious ſtones.

4th, All the compound earths and ſtones fuſe with great eaſe, and form brown glaſs.

5th, All

5th, All ſaline ſubſtances, and even fixed alkali, are ſpeedily volatilized.

6th, Gold, ſilver, &c. and in all probability platina, are ſlowly volatilized and diſperſed at that degree of heat.

7th, All the other metallic ſubſtances, mercury excepted, become oxidated though ſupported on charcoal: they burn on it with a larger or ſmaller flame differently coloured, and at length are entirely diſſipated.

8th, The metallic oxides all burn alſo with flame.

9th, Of the precious ſtones, rubies are ſuſceptible of becoming ſoft, and of fuſing without any alteration of their weight or colour.

The hyacinth fuſes, and readily loſes its colour.

The Saxon topaz, the topaz, and the Brazilian ruby, ſpeedily loſe their colour, and even a fifth of their weight; after which there remains a white earth, ſimilar in appearance to white quartz, or baked porcelain.

The emerald, the chryſolite, and the garnet, ſpeedily fuſe, and form coloured opake glaſs.

10th, The

10th, The diamond burns in the manner of combuſtible bodies, and is entirely diſſipated †.

Of the Means of leſſening the Action of Fire, and deſtroying it entirely.

1118. To diminiſh the action of heat, it will be ſufficient to ſuppreſs the means by which it is increaſed: this ſuppreſſion is the moſt uſual cauſe of the checking or even extinction of fire. That of a ſtove or grate gives leſs heat, if it be deficient in wood or coals; and even though fuel may not be wanting, it becomes languid if not excited by blowing, and is at length extinguiſhed.

1119. But this extinction takes place only ſlowly: there are certain circumſtances under which it is of importance that it ſhould be effected with more ſpeed. It is well known that nothing can burn without the contact of the air (100): to produce that privation of air ſo neceſſary, it will be ſufficient to apply to the ſurface of the burning body any incombuſtible matter, ſuch as water: but, for this purpoſe, the water ought to remain liquid longer than the conflagration can continue; and, conſequently, a great deal of it muſt be applied; for if

---

† For a number of intereſting experiments, of the ſame nature with theſe, performed by the London Philoſophical Society, ſee Philoſophical Magazine, vol. viii.

if only a ſmall quantity of water be thrown on a large fire, as the water experiences a greater degree of heat than that which it can bear in the open air, it becomes decompoſed; its oxygen (276) combines with the combuſtible body, and aſſiſts it to burn; and its hydrogen, combining with caloric, forms inflammable gas; which inſtantly takes fire, and adds greatly to the ſtrength of the conflagration: thus, inſtead of extinguiſhing the fire, it renders it more violent.

Of Refrigeration.

1120. We have already ſhewn (1112) that *inflammation* increaſes as well as the heat, when the burning body is united with others ſuſceptible of catching fire alſo; for in that caſe there is a greater and continued diſengagement of caloric; which, becoming free, renders itſelf ſenſible (1051, 1052). *Heat*, on the other hand, never communicates itſelf without being weakened; becauſe, in this caſe, no new caloric is diſengaged, and that already free, only extends itſelf through a wider ſpace; and it hence follows, that leſs of it remains in the body which communicates the heat. This diminution of caloric in the body is called *Refrigeration*.

1121. As ſome bodies become heated ſooner than others (1088) the caſe is the ſame in regard to refrigeration,

frigeration, as they do not all equally cool in the ſame time. We are not well acquainted with the law according to which refrigeration takes place. We may however ſay in general, that *heat is communicated in the ratio of the maſſes.* For this reaſon more cold is felt on touching a piece of metal than on touching a piece of wood, though they may have the ſame temperature; for refrigeration is the loſs which a body ſuſtains of its caloric, by communicating it to another by contact; and this loſs is nearly proportional to the denſity of the body touched.

1122. If matters which touch each other, or which are mixed, be of the ſame nature, *the exceſs of heat in the hotteſt is communicated to that which has the leaſt heat, in the ratio of their volumes.* If three pints of water be mixed together, the temperature of one being 160 degrees, and that of the other two 40, the temperature of the mixture will be 80 degrees; for 120 degrees, the exceſs of 160 over 40, will be divided among the three pints which have each 40 degrees of temperature.

1123. What has been here ſaid may ſerve to ſhew why ice melts, and the bodies immerſed in it cool. But this refrigeration is much more conſiderable than what is given by the rules we have laid down (1121, 1122); becauſe a great deal of caloric combines with the ice, to make it paſs from the ſolid to the liquid ſtate (348); and that caloric which is ſenſible when in a free ſtate, no longer excites any degree of ſenſible heat when combined (46). In this caſe, therefore, heat is abſorbed and loſt (1042).

1124. Refrigeration being nothing elſe than a diminution of heat, all the effects of heat of which we have ſpoken (1085) muſt ceaſe in a body which cools: 1ſt, That which was flame becomes only thick ſmoke; evaporation is checked, or ceaſes entirely: 2d, Liquefied matters become leſs fluid, and reſume their former conſiſtence: 3d, The volume increaſed by expanſion, is confined within narrower limits.

1125. We are acquainted with no bodies abſolutely cold; ſuch a body would be one containing no caloric in a ſtate of liberty; and no body of this kind has ever yet been found or can exiſt; for free caloric penetrates all bodies in every part, and paſſes freely through their pores from one ſurface to another (16); and ſince it is univerſally diffuſed (1035) there can be no bodies totally deprived of it. We are not therefore acquainted with the zero of heat; it is only a relative quality. Ice is cold when compared with water, and is warm when compared with a mixture of ſalt and ice. Deep cellars are found to be warm in winter, and cold in ſummer, though their temperature is nearly the ſame at all ſeaſons: the reaſon

of

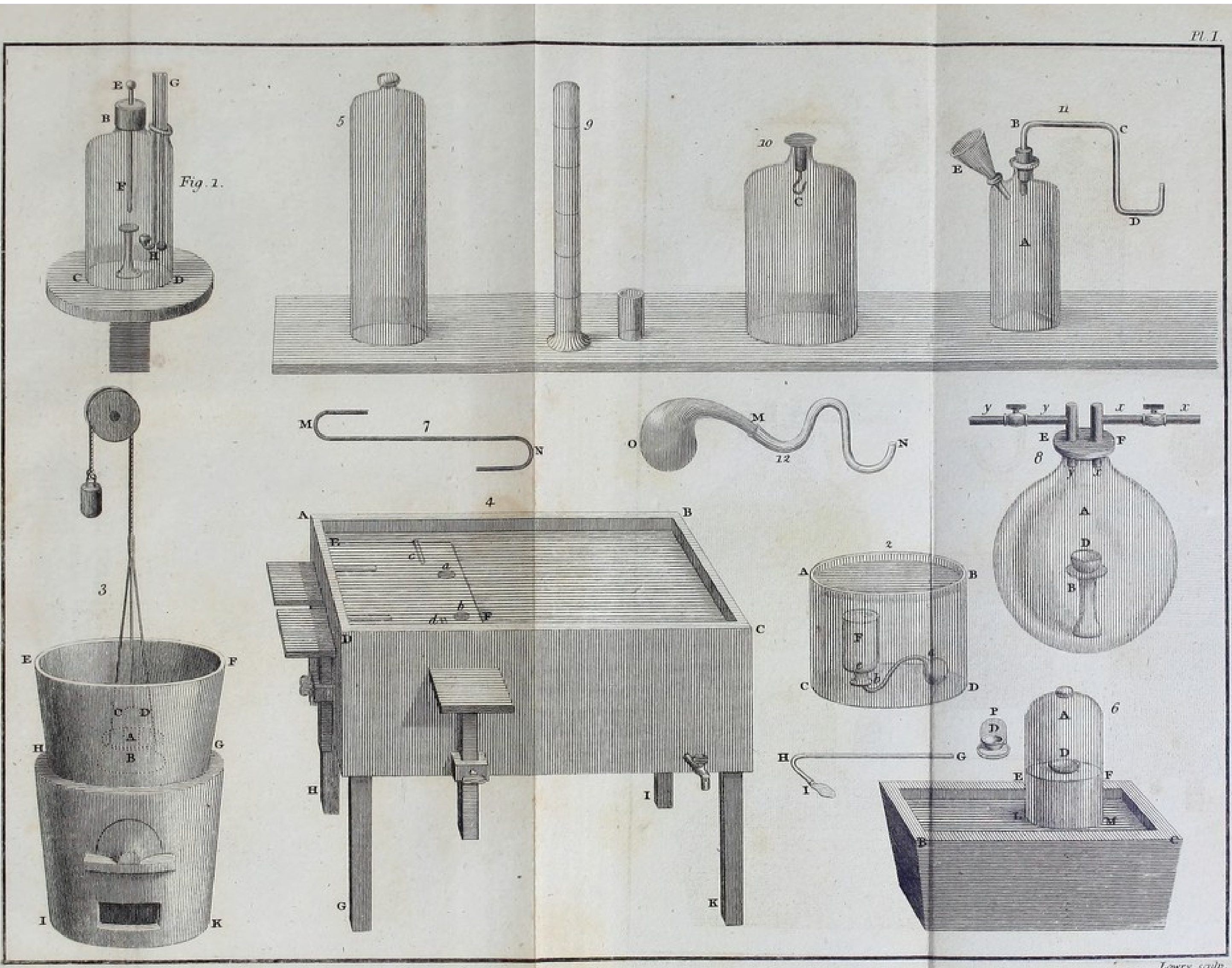
INDEX.

The Figures refer to the Articles, and not to the Pages.

Acid,

Auld, Printer, Greville Street, London.

Pl. I.



Lowry sculp.

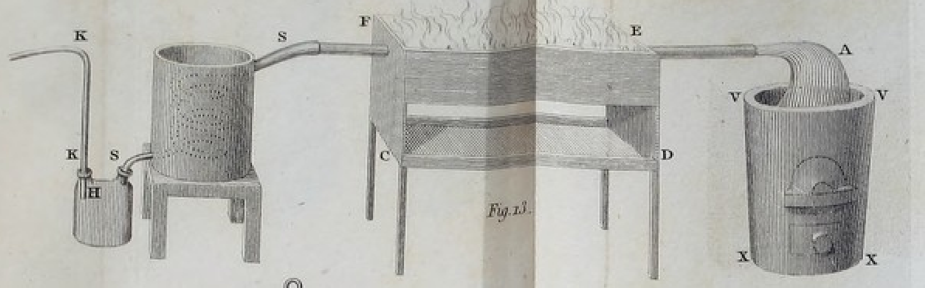
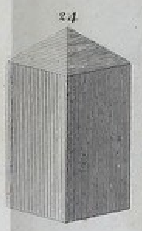
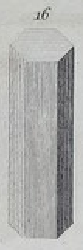


Fig. 13.

24



16



17

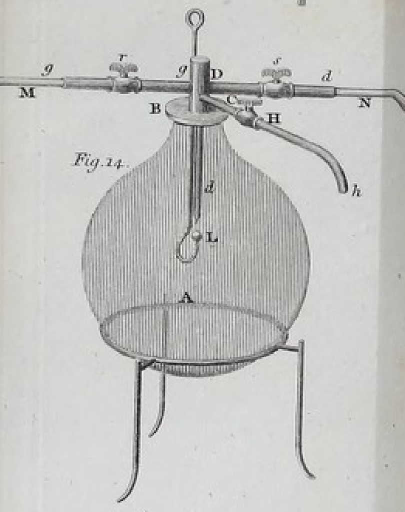
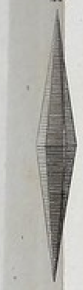
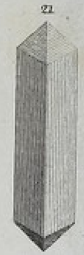


Fig. 14.

22

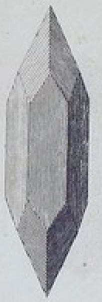


21

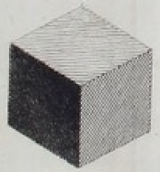


19

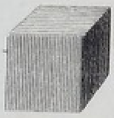
18



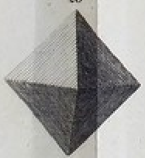
15



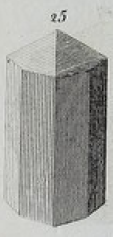
20



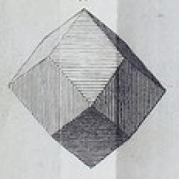
23



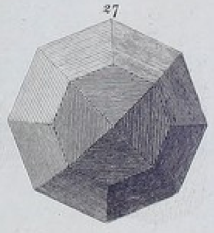
25



26

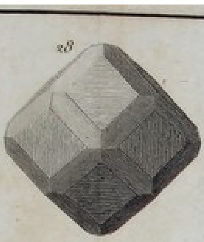


27

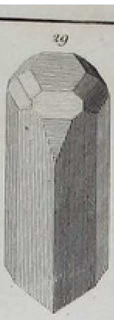


Lowry sculp.

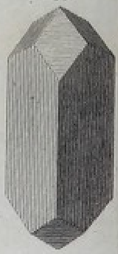
28



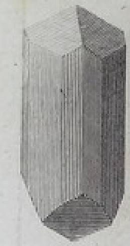
29



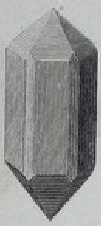
30



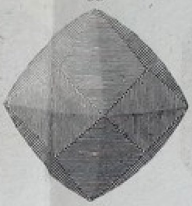
31



32

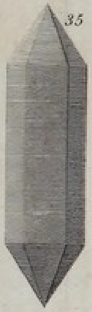


33

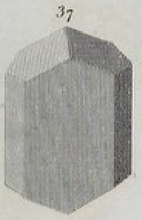


34

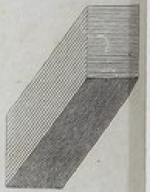
35



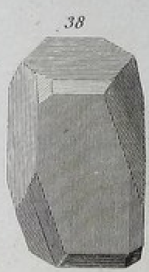
37



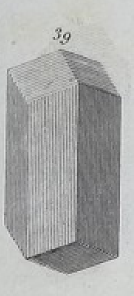
36



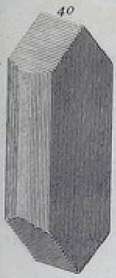
38



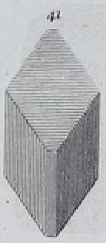
39



40

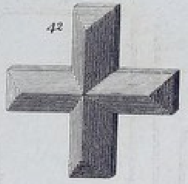


41

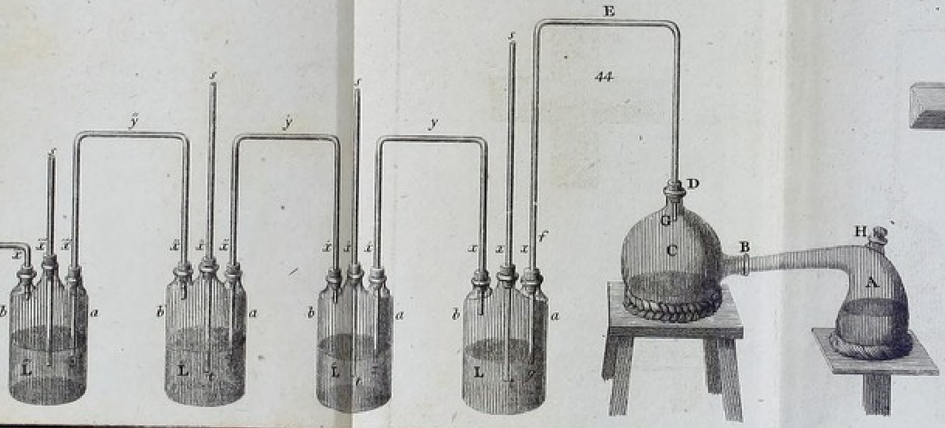


43

42



44



Lowry sculp.

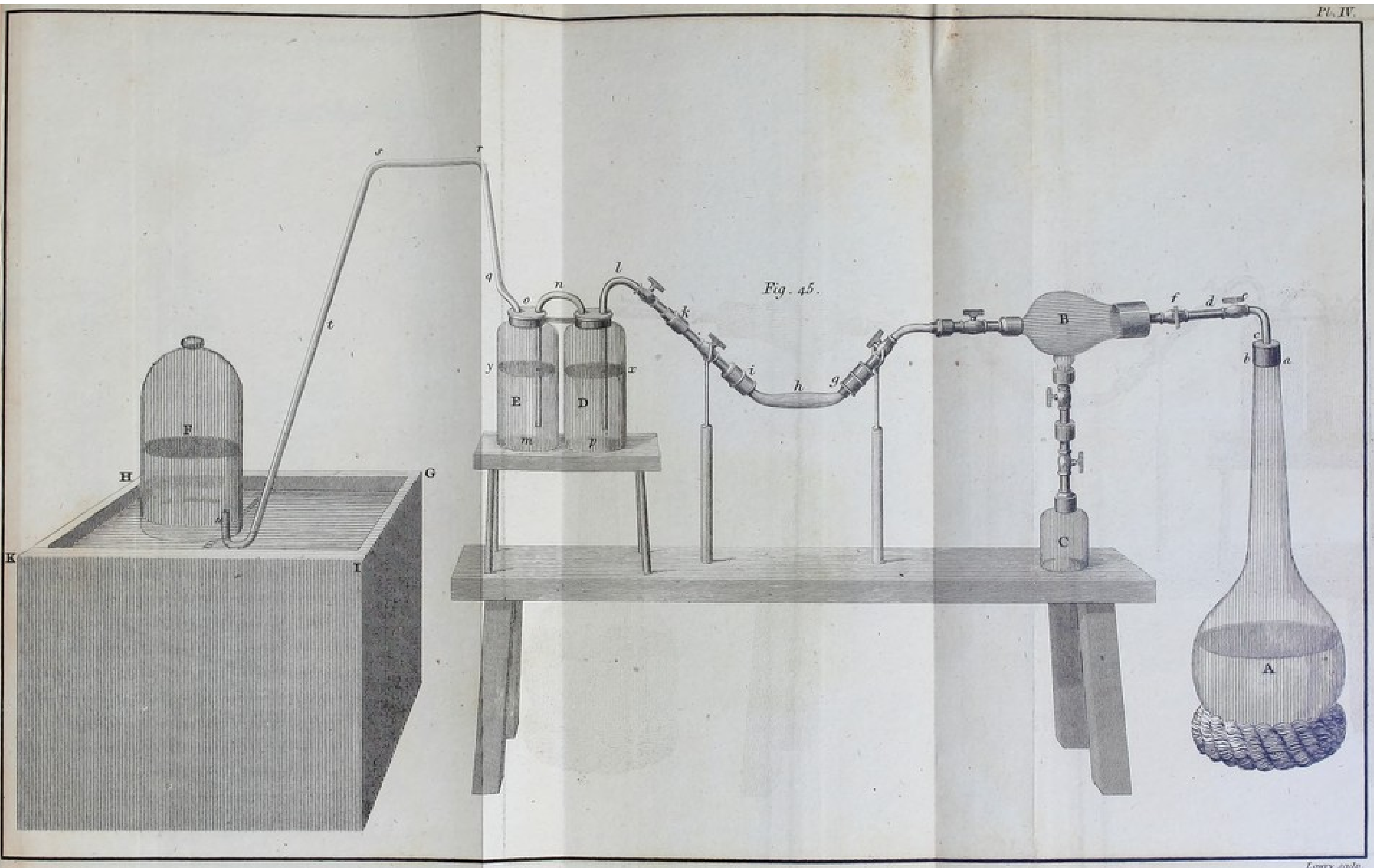
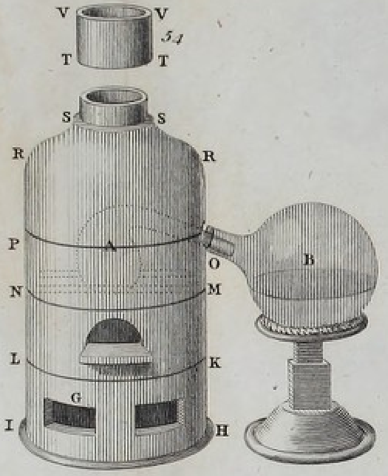


Fig. 45.

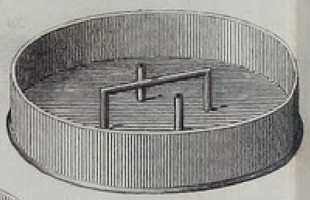
Lowry sculp.

53

54



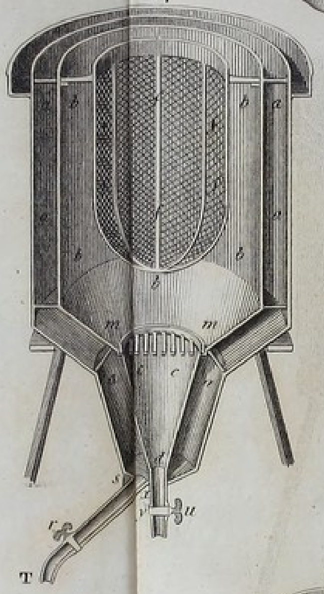
52



51

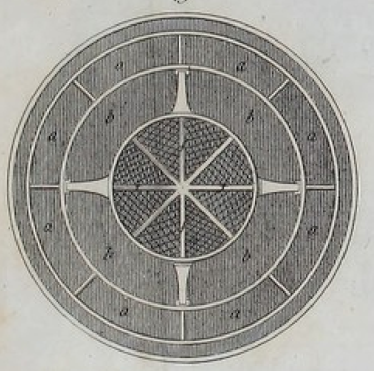
50

47

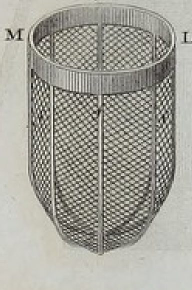


46

49

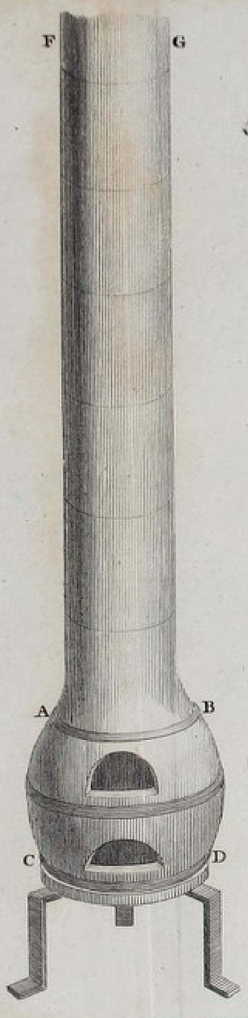


48



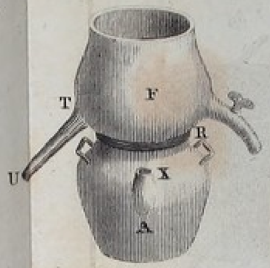
Lowry sculp.

65

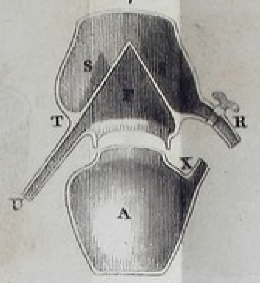


55

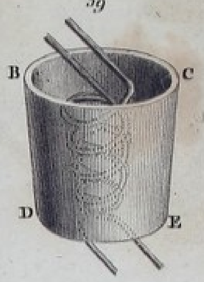
56



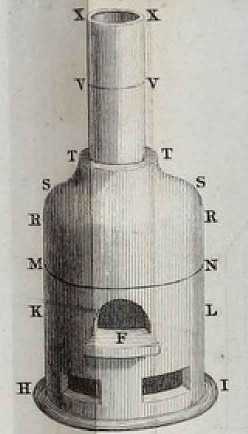
57



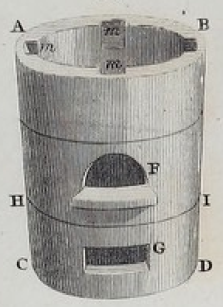
59



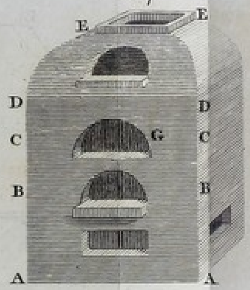
64



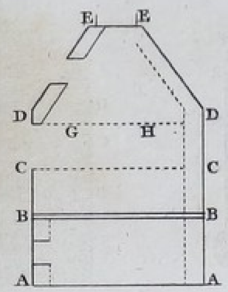
63



67



68



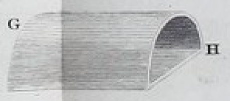
66

60

61

62

69

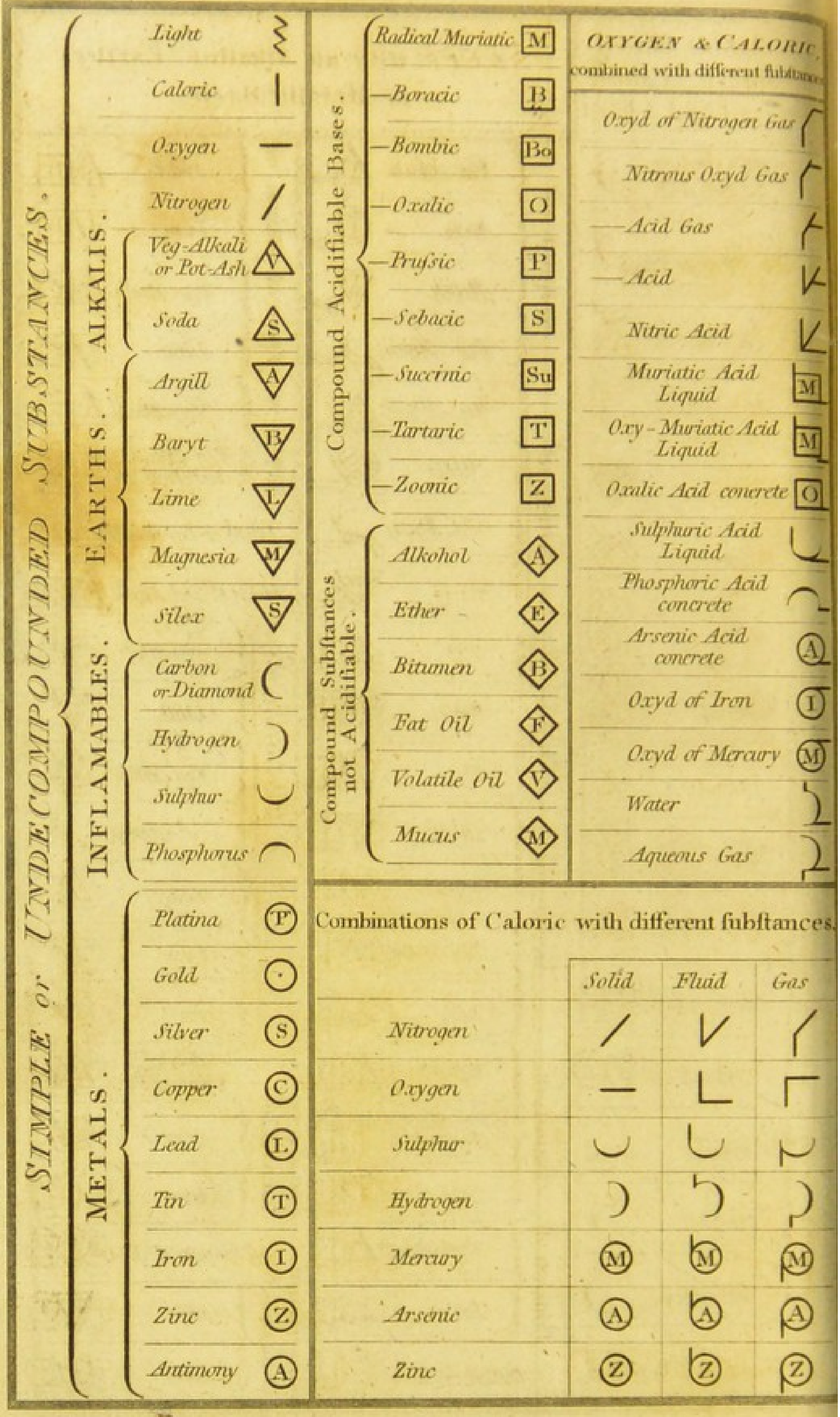


58

Lowry sculp.

CHEMICAL CHARACTERS adopted by the FRENCH CHEMISTS

Plate XVII.



IICAL CHARACTERS adopted by the FRENCH CHEMISTS.

Lowry sculp.