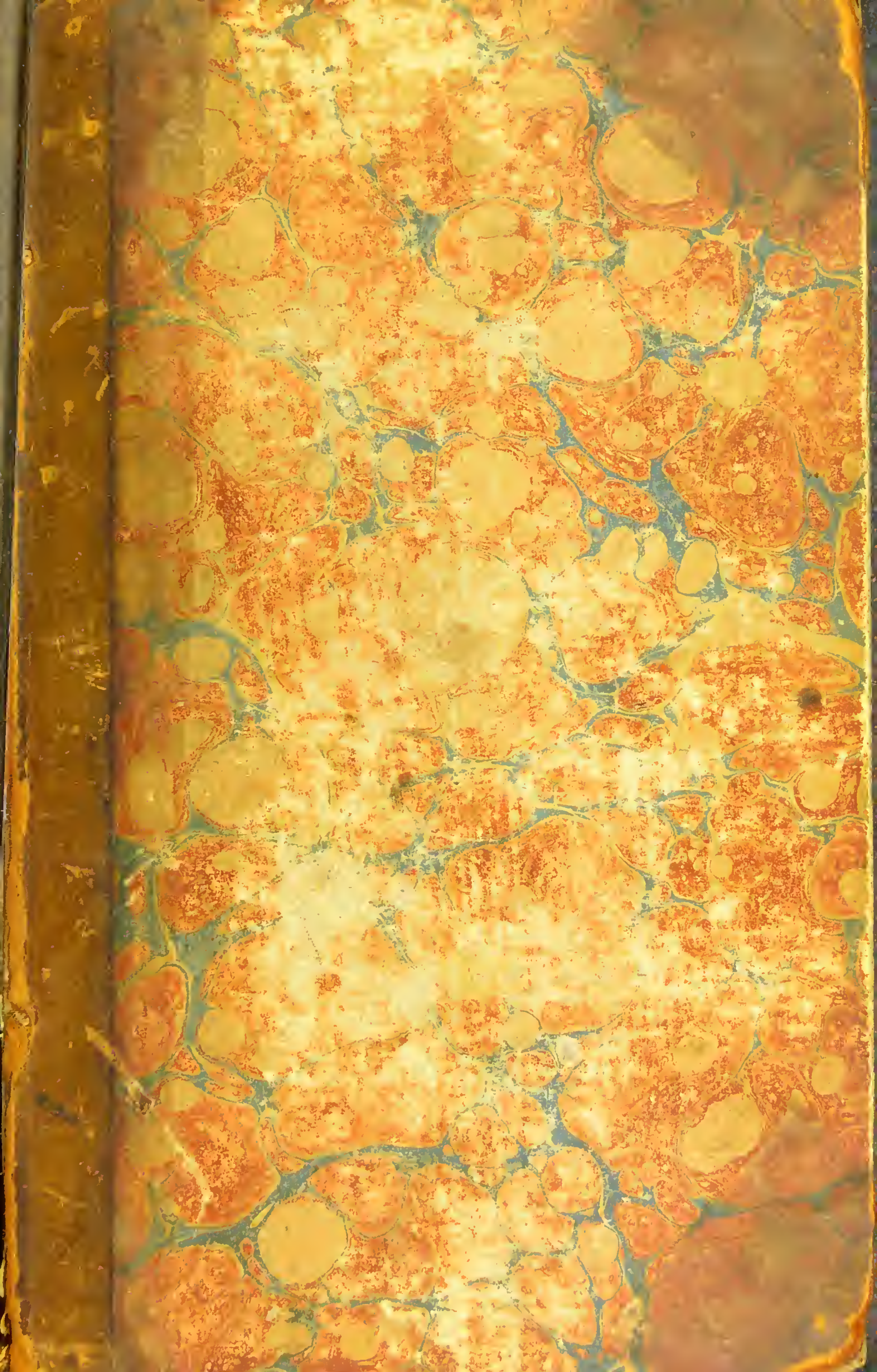


BE

ELEMENTS

OF

CHEMISTRY.

ELEMENTS
OF
CHEMISTRY,
IN A
NEW SYSTEMATIC ORDER,
CONTAINING ALL THE
MODERN DISCOVERIES.

ILLUSTRATED WITH THIRTEEN COPPERPLATES.

BY MR LAVOISIER,
Member of the Academy of Sciences, Royal Society of Medicine, and Agricultural Society of Paris, of the Royal Society of London, and Philoſophical Societies of Orleans, Bologna, Baſil, Philadelphia, Haerlem, Mancheſter, &c. &c.

TRANSLATED FROM THE FRENCH,

BY ROBERT KERR, F.R. & A.SS.E.
Member of the Royal College of Surgeons, and Surgeon to the Orphan Hoſpital of Edinburgh.

EDINBURGH:
PRINTED FOR WILLIAM CREECH, AND SOLD IN
LONDON BY G. G. AND J. J. ROBINSONS.

MDCCXC.

491

ADVERTISEMENT

OF THE

TRANSLATOR.

THE very high character of Mr Lavoiſier as a chemical philoſopher, and the great revolution which, in the opinion of many excellent chemiſts, he has effected in the theory of chemiſtry, has long made it much deſired to have a connected account of his diſcoveries, and of the new theory he has founded upon the modern experiments written by himſelf. This is now accompliſhed by the publication of his Elements of Chemiſtry; therefore no excuſe can be at all neceſſary for giving the following work to the public in an Engliſh dreſs; and the only heſitation of the Tranſlator is with regard to his own abilities for the taſk. He is moſt ready to confeſs, that his knowledge of the compoſition of language fit for publication is far

inferior

inferior to his attachment to the ſubject, and to his deſire of appearing decently before the judgment of the world.

He has earneſtly endeavoured to give the meaning of the Author with the moſt ſcrupulous fidelity, having paid infinitely greater attention to accuracy of tranſlation than to elegance of ſtile. This laſt indeed, had he even, by proper labour, been capable of attaining, he has been obliged, for very obvious reaſons, to neglect, far more than accorded with his wiſhes. The French copy did not reach his hands before the middle of September; and it was judged neceſſary by the Publiſher that the Tranſlation ſhould be ready by the commencement of the Univerſity Seſſion at the end of October.

He at firſt intended to have changed all the weights and meaſures uſed by Mr Lavoiſier into their correſpondent Engliſh denominations, but, upon trial, the taſk was found infinitely too great for the time allowed; and to have executed this part of the work inaccurately, muſt have been both uſeleſs and miſleading to the reader. All that has been attempted in this way is adding, between brackets ( ), the degrees of Fahrenheit's hrenheit's ſcale correſponding with thoſe of Reaumeur's thermometer, which is uſed by the Author. Rules are added, however, in the Appendix, for converting the French weights and meaſures into Engliſh, by which means the reader may at any time calculate ſuch quantities as occur, when deſirous of comparing Mr Lavoiſier's experiments with thoſe of Britiſh authors.

By an overſight, the firſt part of the tranſlation went to preſs without any diſtinction being preſerved between charcoal and its ſimple elementary part, which enters into chemical combinations, eſpecially with oxygen or the acidifying principle, forming carbonic acid. This pure element, which exiſts in great plenty in well made charcoal, is named by Mr Lavoiſier *carbone*, and ought to have been ſo in the tranſlation; but the attentive reader can very eaſily rectify the miſtake. There is an error in Plate XI. which the engraver copied ſtrictly from the original, and which was not diſcovered until the plate was worked off at preſs, when that part of the Elements which treats of the apparatus there repreſented came to be tranſlated. The two tubes 21. and 24. by which the gas is conveyed

into

into the bottles of alkaline ſolution 22. 25. ſhould have been made to dip into the liquor, while the other tubes 23. and 26. which carry off the gas, ought to have been cut off ſome way above the ſurface of the liquor in the bottles.

A few explanatory notes are added; and indeed, from the perſpicuity of the Author, very few were found neceſſary. In a very ſmall number of places, the liberty has been taken of throwing to the bottom of the page, in notes, ſome parenthetical expreſſions, only relative to the ſubject, which, in their original place, tended to confuſe the ſenſe. Theſe, and the original notes of the Author, are diſtinguiſhed by the letter A, and to the few which the Tranſlator has ventured to add, the letter E is ſubjoined.

Mr Lavoiſier has added, in an Appendix, ſeveral very uſeful Tables for facilitating the calculations now neceſſary in the advanced ſtate of modern chemiſtry, wherein the moſt ſcrupulous accuracy is required. It is proper to give ſome account of theſe, and of the reaſons for omitting ſeveral of them.

No.

No. I. of the French Appendix is a Table for converting ounces, gros, and grains, into the decimal fractions of the French pound; and No. II. for reducing theſe decimal fractions again into the vulgar ſubdiviſions. No. III. contains the number of French cubical inches and decimals which correſpond to a determinate weight of water.

The Tranſlator would moſt readily have converted theſe Tables into Engliſh weights and meaſures; but the neceſſary calculations muſt have occupied a great deal more time than could have been ſpared in the period limited for publication. They are therefore omitted, as altogether uſeleſs, in their preſent ſtate, to the Britiſh chemiſt.

No. IV. is a Table for converting lines or twelfth parts of the inch, and twelfth parts of lines, into decimal fractions, chiefly for the purpoſe of making the neceſſary corrections upon the quantities of gaſſes according to their barometrical preſſure. This can hardly be at all uſeful or neceſſary, as the barometers uſed in Britain are graduated in decimal fractions of the inch, but, being referred to by the Author in the text, it has been retained, and is No. 1. of the Appendix to this Tranſlation.

No. V. Is a Table for converting the obſerved heights of water within the jars uſed in pneumato-chemical experiments into correſpondent heights of mercury for correcting the volume of gaſſes. This, in Mr Lavoiſier's Work, is expreſſed for the water in lines, and for the mercury in decimals of the inch, and conſequently, for the reaſons given reſpecting the Fourth Table, muſt have been of no uſe. The Tranſlator has therefore calculated a Table for this correction, in which the water is expreſſed in decimals, as well as the mercury. This Table is No. II. of the Engliſh Appendix.

No. VI. contains the number of French cubical inches and decimals contained in the correſponding ounce-meaſures uſed in the experiments of our celebrated countryman Dr Prieſtley. This Table, which forms No. III. of the Engliſh Appendix, is retained, with the addition of a column, in which the correſponding Engliſh cubical inches and decimals are expreſſed.

No. VII. Is a Table of the weights of a cubical foot and inch, French meaſure, of the different gaſſes expreſſed in French ounces, gros, grains, and decimals. This, which forms No. VI. of the Engliſh Appendix, has been, with conſiderable labour, calculated into Engliſh weight and meaſure.

No. VIII. Gives the ſpecific gravities of a great number of bodies, with columns, containing the weights of a cubical foot and inch, French meaſure, of all the ſubſtances. The ſpecific gravities of this Table, which is No. VII. of the Engliſh Appendix, are retained, but the additional columns, as uſeleſs to the Britiſh philoſopher, are omitted; and to have converted theſe into Engliſh denominations muſt have required very long and painful calculations.

Rules are ſubjoined, in the Appendix to this tranſlation, for converting all the weights and meaſures uſed by Mr Lavoiſier into correſponding Engliſh denominations; and the Tranſlator is proud to acknowledge his obligation to the learned Profeſſor of Natural Philoſophy in the Univerſity of Edinburgh, who kindly ſupplied him with the neceſſary information for this purpoſe. A Table is likewiſe added, No. IV. of the

the Engliſh Appendix, for converting the degrees of Reaumeur's ſcale uſed by Mr Lavoiſier into the correſponding degrees of Fahrenheit, which is univerſally employed in Britain *.

This Tranſlation is ſent into the world with the utmoſt diffidence, tempered, however, with this conſolation, that, though it muſt fall greatly ſhort of the elegance, or even propriety of language, which every writer ought to endeavour to attain, it cannot fail of advancing the intereſts of true chemical ſcience, by diſſeminating the accurate mode of analyſis adopted by its juſtly celebrated Author. Should the public call for a ſecond edition, every care ſhall be taken to correct the forced imperfections of the preſent tranſlation, and to improve the work by valuable additional matter from other authors of reputation in the ſeveral ſubjects treated of.

EDINBURGH,
Oct. 23. 1789.

---

* The Tranſlator has ſince been enabled, by the kind aſſiſtance of the gentleman above alluded to, to give Tables, of the ſame nature with thoſe of Mr Lavoiſier, for facilitating the calculations of the reſults of chemical experiments.

PREFACE

OF THE

AUTHOR.

WHEN I began the following Work, my only object was to extend and explain more fully the Memoir which I read at the public meeting of the Academy of Sciences in the month of April 1787, on the neceſſity of reforming and completing the Nomenclature of Chemiſtry. While engaged in this employment, I perceived, better than I had ever done before, the juſtice of the following maxims of the Abbé de Condillac, in his Syſtem of Logic, and ſome other of his works.

"We think only through the medium of "words.—Languages are true analytical me-

"thods,

" thods.—Algebra, which is adapted to its pur-
" poſe in every ſpecies of expreſſion, in the
" moſt ſimple, moſt exact, and beſt manner
" poſſible, is at the ſame time a language and
" an analytical method.—The art of reaſoning
" is nothing more than a language well aran-
" ged."

Thus, while I thought myſelf employed only in forming a Nomenclature, and while I propoſed to myſelf nothing more than to improve the chemical language, my work transformed itſelf by degrees, without my being able to prevent it, into a treatiſe upon the Elements of Chemiſtry.

The impoſſibility of ſeparating the nomenclature of a ſcience from the ſcience itſelf, is owing to this, that every branch of phyſical ſcience muſt conſiſt of three things; the ſeries of facts which are the objects of the ſcience, the ideas which repreſent theſe facts, and the words by which theſe ideas are expreſſed. Like three impreſſions of the ſame ſeal, the word ought to produce the idea, and the idea to be a picture of the fact. And, as ideas are preſerved and communicated by means of words, it neceſſarily fol-

lows

lows that we cannot improve the language of any ſcience without at the ſame time improving the ſcience itſelf; neither can we, on the other hand, improve a ſcience, without improving the language or nomenclature which belongs to it. However certain the facts of any ſcience may be, and, however juſt the ideas we may have formed of theſe facts, we can only communicate falſe impreſſions to others, while we want words by which theſe may be properly expreſſed.

To thoſe who will conſider it with attention, the firſt part of this treatiſe will afford frequent proofs of the truth of the above obſervations. But as, in the conduct of my work, I have been obliged to obſerve an order of arrangement eſſentially differing from what has been adopted in any other chemical work yet publiſhed, it is proper that I ſhould explain the motives which have led me to do ſo.

It is a maxim univerſally admitted in geometry, and indeed in every branch of knowledge, that, in the progreſs of inveſtigation, we ſhould proceed from known facts to what is unknown. In early infancy, our ideas ſpring from our wants; the ſenſation of want excites the idea of the

the object by which it is to be gratified. In this manner, from a ſeries of ſenſations, obſervations, and analyſes, a ſucceſſive train of ideas ariſes, ſo linked together, that an attentive obſerver may trace back to a certain point the order and connection of the whole ſum of human knowledge.

When we begin the ſtudy of any ſcience, we are in a ſituation, reſpecting that ſcience, ſimilar to that of children; and the courſe by which we have to advance is preciſely the ſame which Nature follows in the formation of their ideas. In a child, the idea is merely an effect produced by a ſenſation; and, in the ſame manner, in commencing the ſtudy of a phyſical ſcience, we ought to form no idea but what is a neceſſary conſequence, and immediate effect, of an experiment or obſervation. Beſides, he that enters upon the career of ſcience, is in a leſs advantageous ſituation than a child who is acquiring his firſt ideas. To the child, Nature gives various means of rectifying any miſtakes he may commit reſpecting the ſalutary or hurtful qualities of the objects which ſurround him. On every occaſion his judgments are corrected by experience; want and pain are the neceſſary con-

conſequences ariſing from falſe judgment; gratification and pleaſure are produced by judging aright. Under ſuch maſters, we cannot fail to become well informed; and we ſoon learn to reaſon juſtly, when want and pain are the neceſſary conſequences of a contrary conduct.

In the ſtudy and practice of the ſciences it is quite different; the falſe judgments we form neither affect our exiſtence nor our welfare; and we are not forced by any phyſical neceſſity to correct them. Imagination, on the contrary, which is ever wandering beyond the bounds of truth, joined to ſelf-love and that ſelf-confidence we are ſo apt to indulge, prompt us to draw concluſions which are not immediately derived from facts; ſo that we become in ſome meaſure intereſted in deceiving ourſelves. Hence it is by no means to be wondered, that, in the ſcience of phyſics in general, men have often made ſuppoſitions, inſtead of forming concluſions. Theſe ſuppoſitions, handed down from one age to another, acquire additional weight from the authorities by which they are ſupported, till at laſt they are received, even by men of genius, as fundamental truths.

The only method of preventing ſuch errors from taking place, and of correcting them when formed, is to reſtrain and ſimplify our reaſoning as much as poſſible. This depends entirely upon ourſelves, and the neglect of it is the only ſource of our miſtakes. We muſt truſt to nothing but facts: Theſe are preſented to us by Nature, and cannot deceive. We ought, in every inſtance, to ſubmit our reaſoning to the teſt of experiment, and never to ſearch for truth but by the natural road of experiment and obſervation. Thus mathematicians obtain the ſolution of a problem by the mere arrangement of data, and by reducing their reaſoning to ſuch ſimple ſteps, to concluſions ſo very obvious, as never to loſe ſight of the evidence which guides them.

Thoroughly convinced of theſe truths, I have impoſed upon myſelf, as a law, never to advance but from what is known to what is unknown; never to form any concluſion which is not an immediate conſequence neceſſarily flowing from obſervation and experiment; and always to arrange the facts, and the concluſions which are drawn from them, in ſuch an order as ſhall render it moſt eaſy for beginners in the ſtudy of chemiſtry thoroughly to underſtand them. Hence I have been obliged to depart from the uſual order of courſes of lectures and of treatiſes upon chemiſtry, which always aſſume the firſt principles of the ſcience, as known, when the pupil or the reader ſhould never be ſuppoſed to know them till they have been explained in ſubſequent leſſons. In almoſt every inſtance, theſe begin by treating of the elements of matter, and by explaining the table of affinities, without conſidering, that, in ſo doing, they muſt bring the principal phenomena of chemiſtry into view at the very outſet: They make uſe of terms which have not been defined, and ſuppoſe the ſcience to be underſtood by the very perſons they are only beginning to teach. It ought likewiſe to be conſidered, that very little of chemiſtry can be learned in a firſt courſe, which is hardly ſufficient to make the language of the ſcience familiar to the ears, or the apparatus familiar to the eyes. It is almoſt impoſſible to become a chemiſt in leſs than three or four years of conſtant application.

Theſe inconveniencies are occaſioned not ſo much by the nature of the ſubject, as by the method of teaching it; and, to avoid them, I was chiefly induced to adopt a new arrangement of chemiſtry, which appeared to me more conſonant to the order of Nature. I acknowledge, however, that in thus endeavouring to avoid difficulties of one kind, I have found myſelf involved in others of a different ſpecies, ſome of which I have not been able to remove; but I am perſuaded, that ſuch as remain do not ariſe from the nature of the order I have adopted, but are rather conſequences of the imperfection under which chemiſtry ſtill labours. This ſcience ſtill has many chaſms, which interrupt the ſeries of facts, and often render it extremely difficult to reconcile them with each other: It has not, like the elements of geometry, the advantage of being a complete ſcience, the parts of which are all cloſely connected together: Its actual progreſs, however, is ſo rapid, and the facts, under the modern doctrine, have aſſumed ſo happy an arrangement, that we have ground to hope, even in our own times, to ſee it approach near to the higheſt ſtate of perfection of which it is ſuſceptible.

The rigorous law from which I have never deviated, of forming no concluſions which are not fully warranted by experiment, and of never ſupplying

ſupplying the abſence of facts, has prevented me from comprehending in this work the branch of chemiſtry which treats of affinities, although it is perhaps the beſt calculated of any part of chemiſtry for being reduced into a completely ſyſtematic body. Meſſrs Geoffroy, Gellert, Bergman, Scheele, De Morveau, Kirwan, and many others, have collected a number of particular facts upon this ſubject, which only wait for a proper arrangement; but the principal data are ſtill wanting, or, at leaſt, thoſe we have are either not ſufficiently defined, or not ſufficiently proved, to become the foundation upon which to build ſo very important a branch of chemiſtry. This ſcience of affinities, or elective attractions, holds the ſame place with regard to the other branches of chemiſtry, as the higher or tranſcendental geometry does with reſpect to the ſimpler and elementary part; and I thought it improper to involve thoſe ſimple and plain elements, which I flatter myſelf the greateſt part of my readers will eaſily underſtand, in the obſcurities and difficulties which ſtill attend that other very uſeful and neceſſary branch of chemical ſcience.

Perhaps a ſentiment of ſelf-love may, without my perceiving it, have given additional force to theſe reflections. Mr de Morveau is at preſent engaged in publiſhing the article *Affinity* in the Methodical Encyclopædia; and I had more reaſons than one to decline entering upon a work in which he is employed.

It will, no doubt, be a matter of ſurpriſe, that in a treatiſe upon the elements of chemiſtry, there ſhould be no chapter on the conſtituent and elementary parts of matter; but I ſhall take occaſion, in this place, to remark, that the fondneſs for reducing all the bodies in nature to three or four elements, proceeds from a prejudice which has deſcended to us from the Greek Philoſophers. The notion of four elements, which, by the variety of their proportions, compoſe all the known ſubſtances in nature, is a mere hypotheſis, aſſumed long before the firſt principles of experimental philoſophy or of chemiſtry had any exiſtence. In thoſe days, without poſſeſſing facts, they framed ſyſtems; while we, who have collected facts, ſeem determined to reject them, when they do not agree with our prejudices. The authority of theſe fathers of human philoſophy ſtill carry great weight, and there is reaſon to fear that it will even bear hard upon generations yet to come.

It

It is very remarkable, that, notwithſtanding of the number of philoſophical chemiſts who have ſupported the doctrine of the four elements, there is not one who has not been led by the evidence of facts to admit a greater number of elements into their theory. The firſt chemiſts that wrote after the revival of letters, conſidered ſulphur and ſalt as elementary ſubſtances entering into the compoſition of a great number of ſubſtances; hence, inſtead of four, they admitted the exiſtence of ſix elements. Beccher aſſumes the exiſtence of three kinds of earth, from the combination of which, in different proportions, he ſuppoſed all the varieties of metallic ſubſtances to be produced. Stahl gave a new modification to this ſyſtem; and ſucceeding chemiſts have taken the liberty to make or to imagine changes and additions of a ſimilar nature. All theſe chemiſts were carried along by the influence of the genius of the age in which they lived, which contented itſelf with aſſertions without proofs; or, at leaſt, often admitted as proofs the ſlighteſt degrees of probability, unſupported by that ſtrictly rigorous analyſis required by modern philoſophy.

All that can be ſaid upon the number and nature of elements is, in my opinion, confined to diſcuſſions entirely of a metaphyſical nature. The ſubject only furniſhes us with indefinite problems, which may be ſolved in a thouſand different ways, not one of which, in all probability, is conſiſtent with nature. I ſhall therefore only add upon this ſubject, that if, by the term *elements*, we mean to expreſs thoſe ſimple and indiviſible atoms of which matter is compoſed, it is extremely probable we know nothing at all about them; but, if we apply the term *elements*, or *principles of bodies*, to expreſs our idea of the laſt point which analyſis is capable of reaching, we muſt admit, as elements, all the ſubſtances into which we are capable, by any means, to reduce bodies by decompoſition. Not that we are entitled to affirm, that theſe ſubſtances we conſider as ſimple may not be compounded of two, or even of a greater number of principles; but, ſince theſe principles cannot be ſeparated, or rather ſince we have not hitherto diſcovered the means of ſeparating them, they act with regard to us as ſimple ſubſtances, and we ought never to ſuppoſe them compounded until experiment and obſervation has proved them to be ſo.

The

The foregoing reflections upon the progreſs of chemical ideas naturally apply to the words by which theſe ideas are to be expreſſed. Guided by the work which, in the year 1787, Meſſrs de Morveau, Berthollet, de Fourcroy, and I compoſed upon the Nomenclature of Chemiſtry, I have endeavoured, as much as poſſible, to denominate ſimple bodies by ſimple terms, and I was naturally led to name theſe firſt. It will be recollected, that we were obliged to retain that name of any ſubſtance by which it had been long known in the world, and that in two caſes only we took the liberty of making alterations; firſt, in the caſe of thoſe which were but newly diſcovered, and had not yet obtained names, or at leaſt which had been known but for a ſhort time, and the names of which had not yet received the ſanction of the public; and, ſecondly, when the names which had been adopted, whether by the ancients or the moderns, appeared to us to expreſs evidently falſe ideas, when they confounded the ſubſtances, to which they were applied, with others poſſeſſed of different, or perhaps oppoſite qualities. We made no ſcruple, in this caſe, of ſubſtituting other names in their room, and the greateſt number of theſe were borrowed from the Greek language. We endeavoured to frame them in ſuch a manner as to expreſs the moſt general and the moſt characteriſtic quality of the ſubſtances; and this was attended with the additional advantage both of aſſiſting the memory of beginners, who find it difficult to remember a new word which has no meaning, and of accuſtoming them early to admit no word without connecting with it ſome determinate idea.

To thoſe bodies which are formed by the union of ſeveral ſimple ſubſtances we gave new names, compounded in ſuch a manner as the nature of the ſubſtances directed; but, as the number of double combinations is already very conſiderable, the only method by which we could avoid confuſion, was to divide them into claſſes. In the natural order of ideas, the name of the claſs or genus is that which expreſſes a quality common to a great number of individuals: The name of the ſpecies, on the contrary, expreſſes a quality peculiar to certain individuals only.

Theſe diſtinctions are not, as ſome may imagine, merely metaphyſical, but are eſtabliſhed by Nature. " A child," ſays the Abbé de Condillac,

dillac, " is taught to give the name *tree* to the " firſt one which is pointed out to him. The " next one he ſees preſents the ſame idea, and " he gives it the ſame name. This he does like- " wiſe to a third and a fourth, till at laſt the " word *tree*, which he firſt applied to an indi- " vidual, comes to be employed by him as the " name of a claſs or a genus, an abſtract idea, " which comprehends all trees in general. But, " when he learns that all trees ſerve not the " ſame purpoſe, that they do not all produce " the ſame kind of fruit, he will ſoon learn to " diſtinguiſh them by ſpecific and particular " names." This is the logic of all the ſciences, and is naturally applied to chemiſtry.

The acids, for example, are compounded of two ſubſtances, of the order of thoſe which we conſider as ſimple; the one conſtitutes acidity, and is common to all acids, and, from this ſubſtance, the name of the claſs or the genus ought to be taken; the other is peculiar to each acid, and diſtinguiſhes it from the reſt, and from this ſubſtance is to be taken the name of the ſpecies. But, in the greateſt number of acids, the two conſtituent elements, the acidifying principle, and

and that which it acidifies, may exiſt in different proportions, conſtituting all the poſſible points of equilibrium or of ſaturation. This is the caſe in the ſulphuric and the ſulphurous acids; and theſe two ſtates of the ſame acid we have marked by varying the termination of the ſpecific name.

Metallic ſubſtances which have been expoſed to the joint action of the air and of fire, loſe their metallic luſtre, increaſe in weight, and aſſume an earthy appearance. In this ſtate, like the acids, they are compounded of a principle which is common to all, and one which is peculiar to each. In the ſame way, therefore, we have thought proper to claſs them under a generic name, derived from the common principle; for which purpoſe, we adopted the term *oxyd;* and we diſtinguiſh them from each other by the particular name of the metal to which each belongs.

Combuſtible ſubſtances, which in acids and metallic oxyds are a ſpecific and particular principle, are capable of becoming, in their turn, common principles of a great number of ſubſtances. The ſulphurous combinations have been

been long the only known ones in this kind. Now, however, we know, from the experiments of Meſſrs Vandermonde, Monge, and Berthollet, that charcoal may be combined with iron, and perhaps with ſeveral other metals; and that, from this combination, according to the proportions, may be produced ſteel, plumbago, &c. We know likewiſe, from the experiments of M. Pelletier, that phoſphorus may be combined with a great number of metallic ſubſtances. Theſe different combinations we have claſſed under generic names taken from the common ſubſtance, with a termination which marks this analogy, ſpecifying them by another name taken from that ſubſtance which is proper to each.

The nomenclature of bodies compounded of three ſimple ſubſtances was attended with ſtill greater difficulty, not only on account of their number, but, particularly, becauſe we cannot expreſs the nature of their conſtituent principles without employing more compound names. In the bodies which form this claſs, ſuch as the neutral ſalts, for inſtance, we had to conſider, 1ſt, The acidifying principle, which is common to them all; 2d, The acidifiable principle which conſtitutes their peculiar acid; 3d, The ſaline, earthy,

earthy, or metallic baſis, which determines the particular ſpecies of ſalt. Here we derived the name of each claſs of ſalts from the name of the acidifiable principle common to all the individuals of that claſs; and diſtinguiſhed each ſpecies by the name of the ſaline, earthy, or metallic baſis, which is peculiar to it.

A ſalt, though compounded of the ſame three principles, may, nevertheleſs, by the mere difference of their proportion, be in three different ſtates. The nomenclature we have adopted would have been defective, had it not expreſſed theſe different ſtates; and this we attained chiefly by changes of termination uniformly applied to the ſame ſtate of the different ſalts.

In ſhort, we have advanced ſo far, that from the name alone may be inſtantly found what the combuſtible ſubſtance is which enters into any combination; whether that combuſtible ſubſtance be combined with the acidifying principle, and in what proportion; what is the ſtate of the acid; with what baſis it is united; whether the ſaturation be exact, or whether the acid or the baſis be in exceſs.

It

It may be eaſily ſuppoſed that it was not poſſible to attain all theſe different objects without departing, in ſome inſtances, from eſtabliſhed cuſtom, and adopting terms which at firſt ſight will appear uncouth and barbarous. But we conſidered that the ear is ſoon habituated to new words, eſpecially when they are connected with a general and rational ſyſtem. The names, beſides, which were formerly employed, ſuch as *powder of algaroth*, *ſalt of alembroth*, *pompholix*, *phagadenic water*, *turbith mineral*, *colcothar*, and many others, were neither leſs barbarous nor leſs uncommon. It required a great deal of practice, and no ſmall degree of memory, to recollect the ſubſtances to which they were applied, much more to recollect the genus of combination to which they belonged. The names of *oil of tartar per deliquium*, *oil of vitriol*, *butter of arſenic and of antimony*, *flowers of zinc*, &c. were ſtill more improper, becauſe they ſuggeſted falſe ideas: For, in the whole mineral kingdom, and particularly in the metallic claſs, there exiſts no ſuch thing as butters, oils, or flowers; and, in ſhort, the ſubſtances to which they give theſe fallacious names, are nothing leſs than rank poiſons.

When we publiſhed our eſſay on the nomenclature of chemiſtry, we were reproached for having changed the language which was ſpoken by our maſters, which they diſtinguiſhed by their authority, and handed down to us. But thoſe who reproach us on this account, have forgotten that it was Bergman and Macquer themſelves who urged us to make this reformation. In a letter which the learned Profeſſor of Upſal, M. Bergman, wrote, a ſhort time before he died, to M. de Morveau, he bids him *ſpare no improper names; thoſe who are learned, will always be learned, and thoſe who are ignorant will thus learn ſooner.*

There is an objection to the work which I am going to preſent to the public, which is perhaps better founded, that I have given no account of the opinion of thoſe who have gone before me; that I have ſtated only my own opinion, without examining that of others. By this I have been prevented from doing that juſtice to my aſſociates, and more eſpecially to foreign chemiſts, which I wiſhed to render them. But I beſeech the reader to conſider, that, if I had filled an elementary work with a multitude of quotations; if I had allowed myſelf to enter into long

long diſſertations on the hiſtory of the ſcience, and the works of thoſe who have ſtudied it, I muſt have loſt ſight of the true object I had in view, and produced a work, the reading of which muſt have been extremely tireſome to beginners. It is not to the hiſtory of the ſcience, or of the human mind, that we are to attend in an elementary treatiſe: Our only aim ought to be eaſe and perſpicuity, and with the utmoſt care to keep every thing out of view which might draw aſide the attention of the ſtudent; it is a road which we ſhould be continually rendering more ſmooth, and from which we ſhould endeavour to remove every obſtacle which can occaſion delay. The ſciences, from their own nature, preſent a ſufficient number of difficulties, though we add not thoſe which are foreign to them. But, beſides this, chemiſts will eaſily perceive, that, in the firſt part of my work, I make very little uſe of any experiments but thoſe which were made by myſelf: If at any time I have adopted, without acknowledgment, the experiments or the opinions of M. Berthollet, M. Fourcroy, M. de la Place, M. Monge, or, in general, of any of thoſe whoſe principles are the ſame with my own, it is owing to this circumſtance, that frequent intercourſe, and the habit of communicating our ideas, our obſervations, and our way of thinking to each other, has eſtabliſhed between us a ſort of community of opinions, in which it is often difficult for every one to know his own.

The remarks I have made on the order which I thought myſelf obliged to follow in the arrangement of proofs and ideas, are to be applied only to the firſt part of this work. It is the only one which contains the general ſum of the doctrine I have adopted, and to which I wiſhed to give a form completely elementary.

The ſecond part is compoſed chiefly of tables of the nomenclature of the neutral ſalts. To theſe I have only added general explanations, the object of which was to point out the moſt ſimple proceſſes for obtaining the different kinds of known acids. This part contains nothing which I can call my own, and preſents only a very ſhort abridgment of the reſults of theſe proceſſes, extracted from the works of different authors.

In the third part, I have given a deſcription, in detail, of all the operations connected with modern chemiſtry. I have long thought that a work

work of this kind was much wanted, and I am convinced it will not be without uſe. The method of performing experiments, and particularly thoſe of modern chemiſtry, is not ſo generally known as it ought to be; and had I, in the different memoirs which I have preſented to the Academy, been more particular in the detail of the manipulations of my experiments, it is probable I ſhould have made myſelf better underſtood, and the ſcience might have made a more rapid progreſs. The order of the different matters contained in this third part appeared to me to be almoſt arbitrary; and the only one I have obſerved was to claſs together, in each of the chapters of which it is compoſed, thoſe operations which are moſt connected with one another. I need hardly mention that this part could not be borrowed from any other work, and that, in the principal articles it contains, I could not derive aſſiſtance from any thing but the experiments which I have made myſelf.

I ſhall conclude this preface by tranſcribing, literally, ſome obſervations of the Abbé de Condillac, which I think deſcribe, with a good deal of truth, the ſtate of chemiſtry at a period not far diſtant from our own. Theſe obſervations were made on a different ſubject; but they will not, on this account, have leſs force, if the application of them be thought juſt.

'Inſtead of applying obſervation to the things 'we wiſhed to know, we have choſen rather to 'imagine them. Advancing from one ill founded 'ſuppoſition to another, we have at laſt be'wildered ourſelves amidſt a multitude of errors. 'Theſe errors becoming prejudices, are, of 'courſe, adopted as principles, and we thus be'wilder ourſelves more and more. The method, 'too, by which we conduct our reaſonings is 'as abſurd; we abuſe words which we do not 'underſtand, and call this the art of reaſoning. 'When matters have been brought this length, 'when errors have been thus accumulated, there 'is but one remedy by which order can be 'reſtored to the faculty of thinking; this is, 'to forget all that we have learned, to trace 'back our ideas to their ſource, to follow the 'train in which they riſe, and, as my Lord Ba'con ſays, to frame the human underſtanding 'anew.

'This remedy becomes the more difficult in 'proportion as we think ourſelves more learn'ed.

'ed. Might it not be thought that works which 'treated of the ſciences with the utmoſt perſpi'cuity, with great preciſion and order, muſt be 'underſtood by every body? The fact is, thoſe 'who have never ſtudied any thing will under'ſtand them better than thoſe who have ſtudied 'a great deal, and eſpecially than thoſe who 'have written a great deal.

At the end of the fifth chapter, the Abbé de Condillac adds: 'But, after all, the ſciences 'have made progreſs, becauſe philoſophers have 'applied themſelves with more attention to ob'ſerve, and have communicated to their lan'guage that preciſion and accuracy which they 'have employed in their obſervations: In cor'recting their language they reaſon better.'

CONTENTS.

PART FIRST.

PART II.

PART III.

APPENDIX.

ELEMENTS

OF

CHEMISTRY.

PART I.

Of the Formation and Decompoſition of Aeriform Fluids—of the Combuſtion of Simple Bodies—and the Formation of Acids.

CHAP. I.

Of the Combinations of Caloric, and the Formation of Elaſtic Aëriform Fluids.

THAT every body, whether ſolid or fluid, is augmented in all its dimenſions by any increaſe of its ſenſible heat, was long ago fully eſtabliſhed as a phyſical axiom, or univerſal propoſition, by the celebrated Boerhaave. Such facts as have been adduced for controverting the generality of this principle offer only fallacious reſults, or, at leaſt, ſuch as are ſo complicated with foreign circumſtances as to miſlead the judgment: But, when we ſeparately conſider the effects, ſo as to deduce each from the cauſe to which they ſeparately belong, it is eaſy to perceive that the ſeparation of particles by heat is a conſtant and general law of nature.

When we have heated a ſolid body to a certain degree, and have thereby cauſed its particles to ſeparate from each other, if we allow the body to cool, its particles again approach each other in the ſame proportion in which they were ſeparated by the increaſed temperature; the body returns through the ſame degrees of expanſion which it before extended through; and, if it be brought back to the ſame temperature from which we ſet out at the commencement of the experiment, it recovers exactly the ſame dimenſions which it formerly occupied. But, as we are ſtill very far from being able to arrive at the degree of abſolute cold, or deprivation of all heat, being unacquainted with any degree of coldneſs which we cannot ſuppoſe capable of ſtill farther augmentation, it follows, that we are ſtill incapable of cauſing the ultimate particles of bodies to approach each other as near as is poſſible; and, conſequently, that the particles of all bodies do not touch each other in any ſtate hitherto known, which, tho' a very ſingular concluſion, is yet impoſſible to be denied.

It is ſuppoſed, that, ſince the particles of bodies are thus continually impelled by heat to ſeparate from each other, they would have no connection between themſelves; and, of conſequence, that there could be no ſolidity in nature, unleſs they were held together by ſome other power which tends to unite them, and, ſo to ſpeak, to chain them together; which power, whatever be its cauſe, or manner of operation, we name Attraction.

Thus the particles of all bodies may be conſidered as ſubjected to the action of two oppoſite powers, the one repulſive, the other attractive, between which they remain in equilibrio. So long as the attractive force remains ſtronger, the body muſt continue in a ſtate of ſolidity; but if, on the contrary, heat has ſo far removed theſe particles from each other, as to place them beyond the ſphere of attraction, they loſe the adheſion they before had with each other, and the body ceaſes to be ſolid.

Water gives us a regular and conſtant example of theſe facts; whilſt below Zero * of the French thermometer, or 32° of Fahrenheit, it

---

* Whenever the degree of heat occurs in this work, it is ſtated by the author according to Reaumur's ſcale. The degrees within brackets are the correſpondent degrees of Fahrenheit's ſcale, added by the tranſlator. E.

it remains ſolid, and is called ice. Above that degree of temperature, its particles being no longer held together by reciprocal attraction, it becomes liquid ; and, when we raiſe its temperature above 80°, (212°) its particles, giving way to the repulſion cauſed by the heat, aſſume the ſtate of vapour or gas, and the water is changed into an aëriform fluid.

The ſame may be affirmed of all bodies in nature : They are either ſolid or liquid, or in the ſtate of elaſtic aëriform vapour, according to the proportion which takes place between the attractive force inherent in their particles, and the repulſive power of the heat acting upon theſe ; or, what amounts to the ſame thing, in proportion to the degree of heat to which they are expoſed.

It is difficult to comprehend theſe phenomena, without admitting them as the effects of a real and material ſubſtance, or very ſubtile fluid, which, inſinuating itſelf between the particles of bodies, ſeparates them from each other ; and, even allowing the exiſtence of this fluid to be hypothetical, we ſhall ſee in the ſequel, that it explains the phenomena of nature in a very ſatisfactory manner.

This ſubſtance, whatever it is, being the cauſe of heat, or, in other words, the ſenſation which we call *warmth* being cauſed by the accumulation of this ſubſtance, we cannot, in ſtrict language,

guage, diſtinguiſh it by the term *heat*; becauſe the ſame name would then very improperly expreſs both cauſe and effect. For this reaſon, in the memoir which I publiſhed in 1777 [*], I gave it the names of *igneous fluid* and *matter of heat*: And, ſince that time, in the work [†] publiſhed by Mr de Morveau, Mr Berthollet, Mr de Fourcroy, and myſelf, upon the reformation of chemical nomenclature, we thought it neceſſary to baniſh all periphraſtic expreſſions, which both lengthen phyſical language, and render it more tedious and leſs diſtinct, and which even frequently does not convey ſufficiently juſt ideas of the ſubject intended. Wherefore, we have diſtinguiſhed the cauſe of heat, or that exquiſitely elaſtic fluid which produces it, by the term of *caloric*. Beſides, that this expreſſion fulfils our object in the ſyſtem which we have adopted, it poſſeſſes this farther advantage, that it accords with every ſpecies of opinion, ſince, ſtrictly ſpeaking, we are not obliged to ſuppoſe this to be a real ſubſtance; it being ſufficient, as will more clearly appear in the ſequel of this work, that it be conſidered as the repulſive cauſe, whatever that may be, which ſeparates the particles of matter from each other; ſo that we

---

[*] Collections of the French Academy of Sciences for that year, p. 420.

[†] Chemical Nomenclature.

we are ſtill at liberty to inveſtigate its effects in an abſtract and mathematical manner.

In the preſent ſtate of our knowledge, we are unable to determine whether light be a modification of caloric, or if caloric be, on the contrary, a modification of light. This, however, is indiſputable, that, in a ſyſtem where only decided facts are admiſſible, and where we avoid, as far as poſſible, to ſuppoſe any thing to be that is not really known to exiſt, we ought proviſionally to diſtinguiſh, by diſtinct terms, ſuch things as are known to produce different effects. We therefore diſtinguiſh light from caloric; though we do not therefore deny that theſe have certain qualities in common, and that, in certain circumſtances, they combine with other bodies almoſt in the ſame manner, and produce, in part, the ſame effects.

What I have already ſaid may ſuffice to determine the idea affixed to the word *caloric;* but there remains a more difficult attempt, which is, to give a juſt conception of the manner in which caloric acts upon other bodies. Since this ſubtile matter penetrates through the pores of all known ſubſtances; ſince there are no veſſels through which it cannot eſcape, and, conſequently, as there are none which are capable of retaining it, we can only come at the knowledge of its properties by effects which are fleeting, and difficultly aſcertainable. It is in theſe

theſe things which we neither ſee nor feel, that it is eſpecially neceſſary to guard againſt the extravagancy of our imagination, which forever inclines to ſtep beyond the bounds of truth, and is very difficultly reſtrained within the narrow line of facts.

We have already ſeen, that the ſame body becomes ſolid, or fluid, or aëriform, according to the quantity of caloric by which it is penetrated; or, to ſpeak more ſtrictly, according as the repulſive force exerted by the caloric is equal to, ſtronger, or weaker, than the attraction of the particles of the body it acts upon.

But, if theſe two powers only exiſted, bodies would become liquid at an indiviſible degree of the thermometer, and would almoſt inſtantaneouſly paſs from the ſolid ſtate of aggregation to that of aëriform elaſticity. Thus water, for inſtance, at the very moment when it ceaſes to be ice, would begin to boil, and would be transformed into an aëriform fluid, having its particles ſcattered indefinitely through the ſurrounding ſpace. That this does not happen, muſt depend upon the action of ſome third power. The preſſure of the atmoſphere prevents this ſeparation, and cauſes the water to remain in the liquid ſtate till it be raiſed to 80° of temperature (212°) above zero of the French thermometer, the quantity of caloric which it receives in the loweſt temperature being inſufficient to overcome the preſſure of the atmoſphere.

Whence it appears that, without this atmoſpheric preſſure, we ſhould not have any permanent liquid, and ſhould only be able to ſee bodies in that ſtate of exiſtence in the very inſtant of melting, as the ſmalleſt additional caloric would inſtantly ſeparate their particles, and diſſipate them through the ſurrounding medium. Beſides, without this atmoſpheric preſſure, we ſhould not even have any aëriform fluids, ſtrictly ſpeaking, becauſe the moment the force of attraction is overcome by the repulſive power of the caloric, the particles would ſeparate themſelves indefinitely, having nothing to give limits to their expanſion, unleſs their own gravity might collect them together, ſo as to form an atmoſphere.

Simple reflection upon the moſt common experiments is ſufficient to evince the truth of theſe poſitions. They are more particularly proved by the following experiment, which I publiſhed in the Memoirs of the French Academy for 1777, p. 426.

Having filled with ſulphuric ether * a ſmall narrow glaſs veſſel, A, (Plate VII. Fig. 17.), ſtanding

---

* As I ſhall afterwards give a definition, and explain the properties of the liquor called *ether*, I ſhall only premiſe here, that it is a very volatile inflammable

ing upon its ſtalk P, the veſſel, which is from twelve to fifteen lines diameter, is to be covered by a wet bladder, tied round its neck with ſeveral turns of ſtrong thread; for greater ſecurity, fix a ſecond bladder over the firſt. The veſſel ſhould be filled in ſuch a manner with the ether, as not to leave the ſmalleſt portion of air between the liquor and the bladder. It is now to be placed under the recipient BCD of an air-pump, of which the upper part B ought to be fitted with a leathern lid, through which paſſes a wire EF, having its point F very ſharp; and in the ſame receiver there ought to be placed the barometer GH. The whole being thus diſpoſed, let the recipient be exhauſted, and then, by puſhing down the wire EF, we make a hole in the bladder. Immediately the ether begins to boil with great violence, and is changed into an elaſtic aëriform fluid, which fills the receiver. If the quantity of ether be ſufficient to leave a few drops in the phial after the evaporation is finiſhed, the elaſtic fluid produced will ſuſtain the mercury in the barometer attached to the air-pump, at eight or ten inches in winter, and from

---

mable liquor, having a conſiderably ſmaller ſpecific gravity than water, or even ſpirit of wine.—A.

twenty to twenty-five in ſummer *. To render this experiment more complete, we may introduce a ſmall thermometer into the phial A, containing the ether, which will deſcend conſiderably during the evaporation.

The only effect produced in this experiment is, the taking away the weight of the atmoſphere, which, in its ordinary ſtate, preſſes on the ſurface of the ether; and the effects reſulting from this removal evidently prove, that, in the ordinary temperature of the earth, ether would always exiſt in an aëriform ſtate, but for the preſſure of the atmoſphere, and that the paſſing of the ether from the liquid to the aëriform ſtate is accompanied by a conſiderable leſſening of heat; becauſe, during the evaporation, a part of the caloric, which was before in a free ſtate, or at leaſt in equilibrio in the ſurrounding bodies, combines with the ether, and cauſes it to aſſume the aëriform ſtate.

The ſame experiment ſucceeds with all evaporable fluids, ſuch as alkohol, water, and even mercury; with this difference, that the atmoſphere formed in the receiver by alkohol only ſupports

---

* It would have been more ſatisfactory if the Author had ſpecified the degrees of the thermometer at which theſe heights of the mercury in the barometer are produced.

ſupports the attached barometer about one inch in winter, and about four or five inches in ſummer; that formed by water, in the ſame ſituation, raiſes the mercury only a few lines, and that by quickſilver but a few fractions of a line. There is therefore leſs fluid evaporated from alkohol than from ether, leſs from water than from alkohol, and ſtill leſs from mercury than from either; conſequently there is leſs caloric employed, and leſs cold produced, which quadrates exactly with the reſults of theſe experiments.

Another ſpecies of experiment proves very evidently that the aëriform ſtate is a modification of bodies dependent on the degree of temperature, and on the preſſure which theſe bodies undergo. In a Memoir read by Mr de la Place and me to the Academy in 1777, which has not been printed, we have ſhown, that, when ether is ſubjected to a preſſure equal to twenty-eight inches of the barometer, or about the medium preſſure of the atmoſphere, it boils at the temperature of about 32° (104), or 33° (106.25°), of the thermometer. Mr de Luc, who has made ſimilar experiments with ſpirit of wine, finds it boils at 67° (182.75°). And all the world knows that water boils at 80° (212°). Now, boiling being only the evaporation of a liquid, or the moment of its paſſing from the fluid to the aëriform ſtate, it is evident that, if we keep

ether

ether continually at the temperature of 33° (106.25°), and under the common preſſure of the atmoſphere, we ſhall have it always in an elaſtic aëriform ſtate; and that the ſame thing will happen with alkohol when above 67° (182.75°), and with water when above 80° (212°); all which are perfectly conformable to the following experiment *.

I filled a large veſſel ABCD (Plate VII. 15 Fig. ~~16.~~) with water, at 35° (110.75°), or 36° (113°); I ſuppoſe the veſſel tranſparent, that we may ſee what takes place in the experiment; and we can eaſily hold the hands in water at that temperature without inconvenience. Into it I plunged ſome narrow necked bottles F, G, which were filled with the water, after which they were turned up, ſo as to reſt on their mouths on the bottom of the veſſel. Having next put ſome ether into a very ſmall matraſs, with its neck *a b c*, twice bent as in the Plate, I plunged this matraſs into the water, ſo as to have its neck inſerted into the mouth of one of the bottles F. Immediately upon feeling the effects of the heat communicated to it by the water in the veſſel ABCD it began to boil; and the caloric entering into combination with it, changed it into elaſtic aëriform fluid, with which I filled ſeveral bottles ſucceſſively, F, G, &c.

This

---

* Vide Memoirs of the French Academy, anno 1780, p. 335.—A.

This is not the place to enter upon the examination of the nature and properties of this aëriform fluid, which is extremely inflammable; but, confining myſelf to the object at preſent in view, without anticipating circumſtances, which I am not to ſuppoſe the reader to know, I ſhall only obſerve, that the ether, from this experiment, is almoſt only capable of exiſting in the aëriform ſtate in our world; for, if the weight of our atmoſphere was only equal to between 20 and 24 inches of the barometer, inſtead of 28 inches, we ſhould never be able to obtain ether in the liquid ſtate, at leaſt in ſummer; and the formation of ether would conſequently be impoſſible upon mountains of a moderate degree of elevation, as it would be converted into gas immediately upon being produced, unleſs we employed recipients of extraordinary ſtrength, together with refrigeration and compreſſion. And, laſtly, the temperature of the blood being nearly that at which ether paſſes from the liquid to the aëriform ſtate, it muſt evaporate in the primae viae, and conſequently it is very probable the medical properties of this fluid depend chiefly upon its mechanical effect.

Theſe experiments ſucceed better with nitrous ether, becauſe it evaporates in a lower temperature than ſulphuric ether. It is more difficult to obtain alkohol in the aëriform ſtate; becauſe, as it requires 67° (182.75°) to reduce it to vapour,

pour, the water of the bath muſt be almoſt boiling, and conſequently it is impoſſible to plunge the hands into it at that temperature.

It is evident that, if water were uſed in the foregoing experiment, it would be changed into gas, when expoſed to a temperature ſuperior to that at which it boils. Although thoroughly convinced of this, Mr de la Place and myſelf judged it neceſſary to confirm it by the following direct experiment. We filled a glaſs jar A, (Plate VII. Fig. 5.) with mercury, and placed it with its mouth downwards in a diſh B, likewiſe filled with mercury, and having introduced about two groſs of water into the jar, which roſe to the top of the mercury at CD; we then plunged the whole apparatus into an iron boiler EFGH, full of boiling ſea-water of the temperature of 85° (~~1~~23.25°), placed upon the furnace GHIK. Immediately upon the water over the mercury attaining the temperature of 80° (212°), it began to boil; and, inſtead of only filling the ſmall ſpace ACD, it was converted into an aëriform fluid, which filled the whole jar; the mercury even deſcended below the ſurface of that in the diſh B; and the jar muſt have been overturned, if it had not been very thick and heavy, and fixed to the diſh by means of iron-wire. Immediately after withdrawing the apparatus from the boiler, the vapour in the jar began to condenſe, and the mercury roſe to its former ſtation; but it returned again to the aëriform ſtate a few ſeconds after replacing the apparatus in the boiler.

We have thus a certain number of ſubſtances, which are convertible into elaſtic aëriform fluids by degrees of temperature, not much ſuperior to that of our atmoſphere. We ſhall afterwards find that there are ſeveral others which undergo the ſame change in ſimilar circumſtances, ſuch as muriatic or marine acid, ammoniac or volatile alkali, the carbonic acid or fixed air, the ſulphurous acid, &c. All of theſe are permanently elaſtic in or about the mean temperature of the atmoſphere, and under its common preſſure.

All theſe facts, which could be eaſily multiplied if neceſſary, give me full right to aſſume, as a general principle, that almoſt every body in nature is ſuſceptible of three ſeveral ſtates of exiſtence, ſolid, liquid, and aëriform, and that theſe three ſtates of exiſtence depend upon the quantity of caloric combined with the body. Henceforwards I ſhall expreſs theſe elaſtic aëriform fluids by the generic term *gas*; and in each ſpecies of gas I ſhall diſtinguiſh between the caloric, which in ſome meaſure ſerves the purpoſe of a ſolvent, and the ſubſtance, which in combination with the caloric, forms the baſe of the gas.

To theſe baſes of the different gaſſes, which are hitherto but little known, we have been obliged to aſſign names; theſe I ſhall point out in Chap. IV. of this work, when I have previouſly given an account of the phenomena attendant upon the heating and cooling of bodies, and when I have eſtabliſhed preciſe ideas concerning the compoſition of our atmoſphere.

We have already ſhown, that the particles of every ſubſtance in nature exiſt in a certain ſtate of equilibrium, between that attraction which tends to unite and keep the particles together, and the effects of the caloric which tends to ſeparate them. Hence the caloric not only ſurrounds the particles of all bodies on every ſide, but fills up every interval which the particles of bodies leave between each other. We may form an idea of this, by ſuppoſing a veſſel filled with ſmall ſpherical leaden bullets, into which a quantity of fine ſand is poured, which, inſinuating into the intervals between the bullets, will fill up every void. The balls, in this compariſon, are to the ſand which ſurrounds them exactly in the ſame ſituation as the particles of bodies are with reſpect to the caloric; with this difference only, that the balls are ſuppoſed to touch each other, whereas the particles of bodies are not in contact, being retained at a ſmall diſtance from each other, by the caloric.

If, inſtead of ſpherical balls, we ſubſtitute ſolid bodies of a hexahedral, octohedral, or any other regular figure, the capacity of the intervals between them will be leſſened, and conſequently will no longer contain the ſame quantity of ſand. The ſame thing takes place, with reſpect to natural bodies; the intervals left between their particles are not of equal capacity, but vary in conſequence of the different figures and magnitude of their particles, and of the diſtance at which theſe particles are maintained, according to the exiſting proportion between their inherent attraction, and the repulſive force exerted upon them by the caloric.

In this manner we muſt underſtand the following expreſſion, introduced by the Engliſh philoſophers, who have given us the firſt preciſe ideas upon this ſubject; *the capacity of bodies for containing the matter of heat.* As compariſons with ſenſible objects are of great uſe in aſſiſting us to form diſtinct notions of abſtract ideas, we ſhall endeavour to illuſtrate this, by inſtancing the phenomena which take place between water and bodies which are wetted and penetrated by it, with a few reflections.

If we immerge equal pieces of different kinds of wood, ſuppoſe cubes of one foot each, into water, the fluid gradually inſinuates itſelf into their pores, and the pieces of wood are augmented both in weight and magnitude: But each ſpecies of wood will imbibe a different quantity of water; the lighter and more porous woods will admit a larger, the compact and cloſer grained will admit of a leſſer quantity; for the proportional quantities of water imbibed by the pieces will depend upon the nature of the conſtituent particles of the wood, and upon the greater or leſſer affinity ſubſiſting between them and water. Very reſinous wood, for inſtance, though it may be at the ſame time very porous, will admit but little water. We may therefore ſay, that the different kinds of wood poſſeſs different capacities for receiving water; we may even determine, by means of the augmentation of their weights, what quantity of water they have actually abſorbed; but, as we are ignorant how much water they contained, previous to immerſion, we cannot determine the abſolute quantity they contain, after being taken out of the water.

The ſame circumſtances undoubtedly take place, with bodies that are immerſed in caloric; taking into conſideration, however, that water is an incompreſſible fluid, whereas caloric is, on the contrary, endowed with very great elaſticity; or, in other words, the particles of caloric have a great tendency to ſeparate from each other, when forced by any other power to approach; this difference muſt of neceſſity occa-

ſion

ſion very conſiderable diverſities in the reſults of experiments made upon theſe two ſubſtances.

Having eſtabliſhed theſe clear and ſimple propoſitions, it will be very eaſy to explain the ideas which ought to be affixed to the following expreſſions, which are by no means ſynonimous, but poſſeſs each a ſtrict and determinate meaning, as in the following definitions:

Free caloric, is that which is not combined in any manner with any other body. But, as we live in a ſyſtem to which caloric has a very ſtrong adheſion, it follows that we are never able to obtain it in the ſtate of abſolute freedom.

Combined caloric, is that which is fixed in bodies by affinity or elective attraction, ſo as to form part of the ſubſtance of the body, even part of its ſolidity.

By the expreſſion *ſpecific caloric* of bodies, we underſtand the reſpective quantities of caloric requiſite for raiſing a number of bodies of the ſame weight to an equal degree of temperature. This proportional quantity of caloric depends upon the diſtance between the conſtituent particles of bodies, and their greater or leſſer degrees of coheſion; and this diſtance, or rather the ſpace or void reſulting from it, is, as I have already obſerved, called the *capacity of bodies for containing caloric.*

Heat, conſidered as a ſenſation, or, in other words, ſenſible heat, is only the effect produced upon our ſentient organs, by the motion or paſſage of caloric, diſengaged from the ſurrounding bodies. In general, we receive impreſſions only in conſequence of motion, and we might eſtabliſh it as an axiom, *That*, WITHOUT MOTION, THERE IS NO SENSATION. This general principle applies very accurately to the ſenſations of heat and cold: When we touch a cold body, the caloric which always tends to become in equilibrio in all bodies, paſſes from our hand into the body we touch, which gives us the feeling or ſenſation of cold. The direct contrary happens, when we touch a warm body, the caloric then paſſing from the body into our hand, produces the ſenſation of heat. If the hand and the body touched be of the ſame temperature, or very nearly ſo, we receive no impreſſion, either of heat or cold, becauſe there is no motion or paſſage of caloric; and thus no ſenſation can take place, without ſome correſpondent motion to occaſion it.

When the thermometer riſes, it ſhows, that free caloric is entering into the ſurrounding bodies: The thermometer, which is one of theſe, receives its ſhare in proportion to its maſs, and to the capacity which it poſſeſſes for containing caloric. The change therefore which takes place upon the thermometer, only announces a change of place of the caloric in thoſe bodies, of which the thermometer forms one part; it only indicates the portion of caloric received, without being a meaſure of the whole quantity diſengaged, diſplaced, or abſorbed.

The moſt ſimple and moſt exact method for determining this latter point, is that deſcribed by Mr de la Place, in the Memoirs of the Academy, No. 1780, p. 364; a ſummary explanation of which will be found towards the concluſion of this work. This method conſiſts in placing a body, or a combination of bodies, from which caloric is diſengaging, in the midſt of a hollow ſphere of ice; and the quantity of ice melted becomes an exact meaſure of the quantity of caloric diſengaged. It is poſſible, by means of the apparatus which we have cauſed to be conſtructed upon this plan, to determine, not as has been pretended, the capacity of bodies for containing heat, but the ratio of the increaſe or diminution of capacity produced by determinate degrees of temperature. It is eaſy with the ſame apparatus, by means of divers combinations of experiments, to determine the quantity of caloric requiſite for converting ſolid ſubſtances into liquids, and liquids into elaſtic aëriform fluids; and, *vice verſa*, what quantity of caloric eſcapes from elaſtic vapours in changing to liquids, and what quantity eſcapes from liquids during their converſion into ſolids. Perhaps,

haps, when experiments have been made with ſufficient accuracy, we may one day be able to determine the proportional quantity of caloric, neceſſary for producing the ſeveral ſpecies of gaſſes. I ſhall hereafter, in a ſeparate chapter, give an account of the principal reſults of ſuch experiments as have been made upon this head.

It remains, before finiſhing this article, to ſay a few words relative to the cauſe of the elaſticity of gaſſes, and of fluids in the ſtate of vapour. It is by no means difficult to perceive that this elaſticity depends upon that of caloric, which ſeems to be the moſt eminently elaſtic body in nature. Nothing is more readily conceived, than that one body ſhould become elaſtic by entering into combination with another body poſſeſſed of that quality. We muſt allow that this is only an explanation of elaſticity, by an aſſumption of elaſticity, and that we thus only remove the difficulty one ſtep farther, and that the nature of elaſticity, and the reaſon for caloric being elaſtic, remains ſtill unexplained. Elaſticity in the abſtract is nothing more than that quality of the particles of bodies by which they recede from each other when forced together. This tendency in the particles of caloric to ſeparate, takes place even at conſiderable diſtances. We ſhall be ſatisfied of this, when we conſider that air is ſuſceptible of undergoing great compreſſion, which ſuppoſes that its particles

ticles were previouſly very diſtant from each other; for the power of approaching together certainly ſuppoſes a previous diſtance, at leaſt equal to the degree of approach. Conſequently, thoſe particles of the air, which are already conſiderably diſtant from each other, tend to ſeparate ſtill farther. In fact, if we produce Boyle's vacuum in a large receiver, the very laſt portion of air which remains ſpreads itſelf uniformly through the whole capacity of the veſſel, however large, fills it completely throughout, and preſſes every where againſt its ſides: We cannot, however, explain this effect, without ſuppoſing that the particles make an effort to ſeparate themſelves on every ſide, and we are quite ignorant at what diſtance, or what degree of rarefaction, this effort ceaſes to act.

Here, therefore, exiſts a true repulſion between the particles of elaſtic fluids; at leaſt, circumſtances take place exactly as if ſuch a repulſion actually exiſted; and we have very good right to conclude, that the particles of caloric mutually repel each other. When we are once permitted to ſuppoſe this repelling force, the *rationale* of the formation of gaſſes, or aëriform fluids, becomes perfectly ſimple; tho' we muſt, at the ſame time, allow, that it is extremely difficult to form an accurate conception of this repulſive force acting upon very minute

particles

particles placed at great diſtances from each other.

It is, perhaps, more natural to ſuppoſe, that the particles of caloric have a ſtronger mutual attraction than thoſe of any other ſubſtance, and that theſe latter particles are forced aſunder in conſequence of this ſuperior attraction between the particles of the caloric, which forces them between the particles of other bodies, that they may be able to reunite with each other. We have ſomewhat analogous to this idea in the phenomena which occur when a dry ſponge is dipt into water: The ſponge ſwells; its particles ſeparate from each other; and all its intervals are filled up by the water. It is evident, that the ſponge, in the act of ſwelling, has acquired a greater capacity for containing water than it had when dry. But we cannot certainly maintain, that the introduction of water between the particles of the ſponge has endowed them with a repulſive power, which tends to ſeparate them from each other; on the contrary, the whole phenomena are produced by means of attractive powers; and theſe are, *firſt*, The gravity of the water, and the power which it exerts on every ſide, in common with all other fluids; *2dly*, The force of attraction which takes place between the particles of the water, cauſing them to unite together; *3dly*, The mutual attraction of the particles of the ſponge with each other; and,

and, *laſtly*, The reciprocal attraction which exiſts between the particles of the ſponge and thoſe of the water. It is eaſy to underſtand, that the explanation of this fact depends upon properly appreciating the intenſity of, and connection between, theſe ſeveral powers. It is probable, that the ſeparation of the particles of bodies, occaſioned by caloric, depends in a ſimilar manner upon a certain combination of different attractive powers, which, in conformity with the imperfection of our knowledge, we endeavour to expreſs by ſaying, that caloric communicates a power of repulſion to the particles of bodies.

CHAP. II.

General Views relative to the Formation and Compoſition of our Atmoſphere.

THESE views which I have taken of the formation of elaſtic aëriform fluids or gaſſes, throw great light upon the original formation of the atmoſpheres of the planets, and particularly that of our earth. We readily conceive, that it muſt neceſſarily conſiſt of a mixture of the following ſubſtances: *Firſt*, Of all bodies that are ſuſceptible of evaporation, or, more ſtrictly ſpeaking, which are capable of retaining the ſtate of aëriform elaſticity in the temperature of our atmoſphere, and under a preſſure equal to that of a column of twenty-eight inches of quickſilver in the barometer; and, *ſecondly*, Of all ſubſtances, whether liquid or ſolid, which are capable of being diſſolved by this mixture of different gaſſes.

The better to determine our ideas relating to this ſubject, which has not hitherto been ſufficiently conſidered, let us, for a moment, conceive what change would take place in the various

rious ſubſtances which compoſe our earth, if its temperature were ſuddenly altered. If, for inſtance, we were ſuddenly tranſported into the region of the planet Mercury, where probably the common temperature is much ſuperior to that of boiling water, the water of the earth, and all the other fluids which are ſuſceptible of the gaſſeous ſtate, at a temperature near to that of boiling water, even quickſilver itſelf, would become rarified; and all theſe ſubſtances would be changed into permanent aëriform fluids or gaſſes, which would become part of the new atmoſphere. Theſe new ſpecies of airs or gaſſes would mix with thoſe already exiſting, and certain reciprocal decompoſitions and new combinations would take place, until ſuch time as all the elective attractions or affinities ſubſiſting amongſt all theſe new and old gaſſeous ſubſtances had operated fully; after which, the elementary principles compoſing theſe gaſſes, being ſaturated, would remain at reſt. We muſt attend to this, however, that, even in the above hypothetical ſituation, certain bounds would occur to the evaporation of theſe ſubſtances, produced by that very evaporation itſelf; for as, in proportion to the increaſe of elaſtic fluids, the preſſure of the atmoſphere would be augmented, as every degree of preſſure tends, in ſome meaſure, to prevent evaporation, and as even the moſt evaporable fluids can reſiſt the operation of a very high temperature without evaporating, if prevented by a proportionally ſtronger compreſſion, water and all other liquids being able to ſuſtain a red heat in Papin's digeſter; we muſt admit, that the new atmoſphere would at laſt arrive at ſuch a degree of weight, that the water which had not hitherto evaporated would ceaſe to boil, and, of conſequence, would remain liquid; ſo that, even upon this ſuppoſition, as in all others of the ſame nature, the increaſing gravity of the atmoſphere would find certain limits which it could not exceed. We might even extend theſe reflections greatly farther, and examine what change might be produced in ſuch ſituations upon ſtones, ſalts, and the greater part of the fuſible ſubſtances which compoſe the maſs of our earth. Theſe would be ſoftened, fuſed, and changed into fluids, &c.: But theſe ſpeculations carry me from my object, to which I haſten to return.

By a contrary ſuppoſition to the one we have been forming, if the earth were ſuddenly tranſported into a very cold region, the water which at preſent compoſes our ſeas, rivers, and ſprings, and probably the greater number of the fluids we are acquainted with, would be converted into ſolid mountains and hard rocks, at firſt diaphanous

aphanous and homogeneous, like rock cryſtal, but which, in time, becoming mixed with foreign and heterogeneous ſubſtances, would become opake ſtones of various colours. In this caſe, the air, or at leaſt ſome part of the aëriform fluids which now compoſe the maſs of our atmoſphere, would doubtleſs loſe its elaſticity for want of a ſufficient temperature to retain them in that ſtate: They would return to the liquid ſtate of exiſtence, and new liquids would be formed, of whoſe properties we cannot, at preſent, form the moſt diſtant idea.

Theſe two oppoſite ſuppoſitions give a diſtinct proof of the following corollaries: *Firſt*, That *ſolidity*, *liquidity*, and *aëriform elaſticity*, are only three different ſtates of exiſtence of the ſame matter, or three particular modifications which almoſt all ſubſtances are ſuſceptible of aſſuming ſucceſſively, and which ſolely depend upon the degree of temperature to which they are expoſed; or, in other words, upon the quantity of caloric with which they are penetrated *. 2*dly*, That it is extremely probable that air is a fluid naturally exiſting in a ſtate of vapour; or, as we may better expreſs it, that our atmoſphere is a compound of all the fluids which

---

* The degree of preſſure which they undergo muſt be taken into account. E.

which are ſuſceptible of the vaporous or permanently elaſtic ſtate, in the uſual temperature, and under the common preſſure. *3dly*, That it is not impoſſible we may diſcover, in our atmoſphere, certain ſubſtances naturally very compact, even metals themſelves; as a metallic ſubſtance, for inſtance, only a little more volatile than mercury, might exiſt in that ſituation.

Amongſt the fluids with which we are acquainted, ſome, as water and alkohol, are ſuſceptible of mixing with each other in all proportions; whereas others, on the contrary, as quickſilver, water, and oil, can only form a momentary union; and, after being mixed together, ſeparate and arrange themſelves according to their ſpecific gravities. The ſame thing ought to, or at leaſt may, take place in the atmoſphere. It is poſſible, and even extremely probable, that, both at the firſt creation, and every day, gaſſes are formed, which are difficultly miſcible with atmoſpheric air, and are continually ſeparating from it. If theſe gaſſes be ſpecifically lighter than the general atmoſpheric maſs, they muſt, of courſe, gather in the higher regions, and form ſtrata that float upon the common air. The phenomena which accompany igneous meteors induce me to believe, that there exiſts in the upper parts of of our atmoſphere a ſtratum of inflammable fluid in contact with thoſe ſtrata of air which produce the phenomena of the aurora borealis and other fiery meteors.—I mean hereafter to purſue this ſubject in a ſeparate treatiſe.

CHAP.

CHAP. III.

Analyſis of Atmoſpheric Air, and its Diviſion into two Elaſtic Fluids; the one fit for Reſpiration, the other incapable of being reſpired.

FROM what has been premiſed, it follows, that our atmoſphere is compoſed of a mixture of every ſubſtance capable of retaining the gaſſeous or aëriform ſtate in the common temperature, and under the uſual preſſure which it experiences. Theſe fluids conſtitute a maſs, in ſome meaſure homogeneous, extending from the ſurface of the earth to the greateſt height hitherto attained, of which the denſity continually decreaſes in the inverſe ratio of the ſuperincumbent weight. But, as I have before obſerved, it is poſſible that this firſt ſtratum is ſurmounted by ſeveral others conſiſting of very different fluids.

Our buſineſs, in this place, is to endeavour to determine, by experiments, the nature of the elaſtic fluids which compoſe the inferior ſtratum of air which we inhabit. Modern chemiſtry has made great advances in this reſearch; and it will appear by the following details that the analyſis of atmoſpherical air has been more rigo-

rigorouſly determined than that of any other ſubſtance of the claſs. Chemiſtry affords two general methods of determining the conſtituent principles of bodies, the method of analyſis, and that of ſyntheſis. When, for inſtance, by combining water with alkohol, we form the ſpecies of liquor called, in commercial language, brandy or ſpirit of wine, we certainly have a right to conclude, that brandy, or ſpirit of wine, is compoſed of alkohol combined with water. We can produce the ſame reſult by the analytical method; and in general it ought to be conſidered as a principle in chemical ſcience, never to reſt ſatisfied without both theſe ſpecies of proofs.

We have this advantage in the analyſis of atmoſpherical air, being able both to decompound it, and to form it a-new in the moſt ſatisfactory manner. I ſhall, however, at preſent confine myſelf to recount ſuch experiments as are moſt concluſive upon this head; and I may conſider moſt of theſe as my own, having either firſt invented them, or having repeated thoſe of others, with the intention of analyſing atmoſpherical air, in perfectly new points of view.

I took a matraſs (A, fig. 14. plate II.) of about 36 cubical inches capacity, having a long neck B C D E, of ſix or ſeven lines internal diameter, and having bent the neck as in Plate IV. Fig. 2. ſo as to allow of its being placed in

the

the furnace M M N N, in ſuch a manner that the extremity of its neck E might be inſerted under a bell-glaſs F G, placed in a trough of quickſilver R R S S; I introduced four ounces of pure mercury into the matraſs, and, by means of a ſyphon, exhauſted the air in the receiver F G, ſo as to raiſe the quickſilver to L L, and I carefully marked the height at which it ſtood by paſting on a ſlip of paper. Having accurately noted the height of the thermometer and barometer, I lighted a fire in the furnace M M N N, which I kept up almoſt continually during twelve days, ſo as to keep the quickſilver always almoſt at its boiling point. Nothing remarkable took place during the firſt day: The Mercury, though not boiling, was continually evaporating, and covered the interior ſurface of the veſſels with ſmall drops, at firſt very minute, which gradually augmenting to a ſufficient ſize, fell back into the maſs at the bottom of the veſſel. On the ſecond day, ſmall red particles began to appear on the ſurface of the mercury, which, during the four or five following days, gradually increaſed in ſize and number; after which they ceaſed to increaſe in either reſpect. At the end of twelve days, ſeeing that the calcination of the mercury did not at all increaſe, I extinguiſhed the fire, and allowed the veſſels to cool. The bulk of air in the body and neck of the matraſs, and in the bell-glaſs, reduced to a medium of 28 inches of the barometer and 10° (54.5°) of the thermometer, at the commencement of the experiment was about 50 cubical inches. At the end of the experiment the remaining air, reduced to the ſame medium preſſure and temperature, was only between 42 and 43 cubical inches; conſequently it had loſt about $\frac{1}{6}$ of its bulk. Afterwards, having collected all the red particles, formed during the experiment, from the running mercury in which they floated, I found theſe to amount to 45 grains.

I was obliged to repeat this experiment ſeveral times, as it is difficult in one experiment both to preſerve the whole air upon which we operate, and to collect the whole of the red particles, or calx of mercury, which is formed during the calcination. It will often happen in the ſequel, that I ſhall, in this manner, give in one detail the reſults of two or three experiments of the ſame nature.

The air which remained after the calcination of the mercury in this experiment, and which was reduced to $\frac{5}{6}$ of its former bulk, was no longer fit either for reſpiration or for combuſtion; animals being introduced into it were ſuffocated in a few ſeconds, and when a taper was plunged into it, it was extinguiſhed as if it had been immerſed into water.

In the next place, I took the 45 grains of red matter formed during this experiment, which I put into a ſmall glaſs retort, having a proper apparatus for receiving ſuch liquid, or gaſſeous product, as might be extracted : Having applied a fire to the retort in a furnace, I obſerved that, in proportion as the red matter became heated, the intenſity of its colour augmented. When the retort was almoſt red hot, the red matter began gradually to decreaſe in bulk, and in a few minutes after it diſappeared altogether ; at the ſame time $41\frac{1}{2}$ grains of running mercury were collected in the recipient, and 7 or 8 cubical inches of elaſtic fluid, greatly more capable of ſupporting both reſpiration and combuſtion than atmoſperical air, were collected in the bell-glaſs.

A part of this air being put into a glaſs tube of about an inch diameter, ſhowed the following properties : A taper burned in it with a dazzling ſplendour, and charcoal, inſtead of conſuming quietly as it does in common air, burnt with a flame, attended with a decrepitating noiſe, like phoſphorus, and threw out ſuch a brilliant light that the eyes could hardly endure it. This ſpecies of air was diſcovered almoſt at the ſame time by Mr Prieſtley, Mr Scheele, and myſelf. Mr Prieſtley gave it the name of *dephlogiſticated air*, Mr Scheele called it *empyreal air*. At firſt I named it *highly reſpirable air*, to which

which has ſince been ſubſtituted the term of *vital air*. We ſhall preſently ſee what we ought to think of theſe denominations.

In reflecting upon the circumſtances of this experiment, we readily perceive, that the mercury, during its calcination, abſorbs the ſalubrious and reſpirable part of the air, or, to ſpeak more ſtrictly, the baſe of this reſpirable part; that the remaining air is a ſpecies of mephitis, incapable of ſupporting combuſtion or reſpiration; and conſequently that atmoſpheric air is compoſed of two elaſtic fluids of different and oppoſite qualities. As a proof of this important truth, if we recombine theſe two elaſtic fluids, which we have ſeparately obtained in the above experiment, viz. the 42 cubical inches of mephitis, with the 8 cubical inches of reſpirable air, we reproduce an air preciſely ſimilar to that of the atmoſphere, and poſſeſſing nearly the ſame power of ſupporting combuſtion and reſpiration, and of contributing to the calcination of metals.

Although this experiment furniſhes us with a very ſimple means of obtaining the two principal elaſtic fluids which compoſe our atmoſphere, ſeparate from each other, yet it does not give us an exact idea of the proportion in which theſe two enter into its compoſition: For the attraction of mercury to the reſpirable part of the air, or rather to its baſe, is not ſufficiently ſtrong to overcome all the circumſtances which oppoſe this union. Theſe obſtacles are the mutual adheſion of the two conſtituent parts of the atmoſphere for each other, and the elective attraction which unites the baſe of vital air with caloric; in conſequence of theſe, when the calcination ends, or is at leaſt carried as far as is poſſible, in a determinate quantity of atmoſpheric air, there ſtill remains a portion of reſpirable air united to the mephitis, which the mercury cannot ſeparate. I ſhall afterwards ſhow, that, at leaſt in our climate, the atmoſpheric air is compoſed of reſpirable and mephitic airs, in the proportion of 27 and 73; and I ſhall then diſcuſs the cauſes of the uncertainty which ſtill exiſts with reſpect to the exactneſs of that proportion.

Since, during the calcination of mercury, air is decompoſed, and the baſe of its reſpirable part is fixed and combined with the mercury, it follows, from the principles already eſtabliſhed, that caloric and light muſt be diſengaged during the proceſs: But the two following cauſes prevent us from being ſenſible of this taking place: As the calcination laſts during ſeveral days, the diſengagement of caloric and light, ſpread out in a conſiderable ſpace of time, becomes extremely ſmall for each particular moment of that time, ſo as not to be perceptible; and, in the next place, the operation being carried on by means of fire in a furnace, the heat produced by the calcination itſelf becomes confounded with that proceeding from the furnace. I might add the reſpirable part of the air, or rather its baſe, in entering into combination with the mercury, does not part with all the caloric which it contained, but ſtill retains a part of it after forming the new compound; but the diſcuſſion of this point, and its proofs from experiment, do not belong to this part of our ſubject.

It is, however, eaſy to render this diſengagement of caloric and light evident to the ſenſes, by cauſing the decompoſition of air to take place in a more rapid manner. And for this purpoſe, iron is excellently adapted, as it poſſeſſes a much ſtronger affinity for the baſe of reſpirable air than mercury. The elegant experiment of Mr Ingenhouz, upon the combuſtion of iron, is well known. Take a piece of fine iron wire, twiſted into a ſpiral, (BC, Plate IV. Fig. 17.) fix one of its extremities B into the cork A, adapted to the neck of the bottle DEFG, and fix to the other extremity of the wire C, a ſmall morſel of tinder. Matters being thus prepared, fill the bottle DEFG with air deprived of its mephitic part; then light the tinder, and introduce it quickly with the wire upon which it is fixed, into the bottle which you ſtop up with the cork A, as is ſhown in the figure (17 Plate IV.) The inſtant the tinder

tinder comes into contact with the vital air it begins to burn with great intenſity; and, communicating the inflammation to the iron-wire, it too takes fire, and burns rapidly, throwing out brilliant ſparks, which fall to the bottom of the veſſel in rounded globules, which become black in cooling, but retain a degree of metallic ſplendour. The iron thus burnt is more brittle even than glaſs, and is eaſily reduced into powder, and is ſtill attractable by the magnet, though not ſo powerfully as it was before combuſtion. As Mr Ingenhouz has neither examined the change produced on iron, nor upon the air by this operation, I have repeated the experiment under different circumſtances, in an apparatus adapted to anſwer my particular views, as follows.

Having filled a bell-glaſs (A, Plate IV. Fig. 3.) of about ſix pints meaſure, with pure air, or the highly reſpirable part of air, I tranſported this jar by means of a very flat veſſel, into a quickſilver bath in the baſon BC, and I took care to render the ſurface of the mercury perfectly dry both within and without the jar with blotting paper. I then provided a ſmall capſule of china-ware D, very flat and open, in which I placed ſome ſmall pieces of iron, turned ſpirally, and arranged in ſuch a way as ſeemed moſt favourable for the combuſtion being communicated to every part. To the end of one of theſe pieces of iron was fixed

fixed a ſmall morſel of tinder, to which was added about the ſixteenth part of a grain of phoſphorus, and, by raiſing the bell-glaſs a little, the china capſule, with its contents, were introduced into the pure air. I know that, by this means, ſome common air muſt mix with the pure air in the glaſs; but this, when it is done dexterouſly, is ſo very trifling, as not to injure the ſucceſs of the experiment. This being done, a part of the air is ſucked out from the bell-glaſs, by means of a ſyphon GHI, ſo as to raiſe the mercury within the glaſs to EF; and, to prevent the mercury from getting into the ſyphon, a ſmall piece of paper is twiſted round its extremity. In ſucking out the air, if the motion of the lungs only be uſed, we cannot make the mercury riſe above an inch or an inch and a half; but, by properly uſing the muſcles of the mouth, we can, without difficulty, cauſe it to riſe ſix or ſeven inches.

I next took an iron wire, (MN, Plate IV. Fig. 16.) properly bent for the purpoſe, and making it red hot in the fire, paſſed it through the mercury into the receiver, and brought it in contact with the ſmall piece of phoſphorus attached to the tinder. The phoſphorus inſtantly takes fire, which communicates to the tinder, and from that to the iron. When the pieces have been properly arranged, the whole iron burns, even to the laſt particle, throwing out a white brilliant light ſimilar to that of Chineſe fireworks. The great heat produced by this combuſtion melts the iron into round globules of different ſizes, moſt of which fall into the China cup ; but ſome are thrown out of it, and ſwim upon the ſurface of the mercury. At the beginning of the combuſtion, there is a ſlight augmentation in the volume of the air in the bell-glaſs, from the dilatation cauſed by the heat ; but, preſently afterwards, a rapid diminution of the air takes place, and the mercury riſes in the glaſs ; inſomuch that, when the quantity of iron is ſufficient, and the air operated upon is very pure, almoſt the whole air employed is abſorbed.

It is proper to remark in this place, that, unleſs in making experiments for the purpoſe of diſcovery, it is better to be contented with burning a moderate quantity of iron ; for, when this experiment is puſhed too far, ſo as to abſorb much of the air, the cup D, which floats upon the quickſilver, approaches too near the bottom of the bell-glaſs ; and the great heat produced, which is followed by a very ſudden cooling, occaſioned by the contact of the cold mercury, is apt to break the glaſs. In which caſe, the ſudden fall of the column of mercury, which happens the moment the leaſt flaw is produced in the glaſs, cauſes ſuch a wave, as throws a great part of the quickſilver from the baſon. To a-

void

void this inconvenience, and to enſure ſucceſs to the experiment, one groſs and a half of iron is ſufficient to burn in a bell-glaſs, which holds about eight pints of air. The glaſs ought likewiſe to be ſtrong, that it may be able to bear the weight of the column of mercury which it has to ſupport.

By this experiment, it is not poſſible to determine, at one time, both the additional weight acquired by the iron, and the changes which have taken place in the air. If it is wiſhed to aſcertain what additional weight has been gained by the iron, and the proportion between that and the air abſorbed, we muſt carefully mark upon the bell-glaſs, with a diamond, the height of the mercury, both before and after the experiment *. After this, the ſyphon (GH, Pl. IV. fig. 3.) guarded, as before, with a bit of paper, to prevent its filling with mercury, is to be introduced under the bell-glaſs, having the thumb placed upon the extremity, G, of the ſyphon, to regulate the paſſage of the air; and by this means the air is gradually admitted, ſo as to let the mercury fall to its level. This being done, the bell-glaſs is to be carefully removed, the globules

---

* It will likewiſe be neceſſary to take care that the air contained in the glaſs, both before and after the experiment, be reduced to a common temperature and preſſure, otherwiſe the reſults of the following calculations will be fallacious.—E.

globules of melted iron contained in the cup, and thoſe which have been ſcattered about, and ſwim upon the mercury, are to be accurately collected, and the whole is to be weighed. The iron will be found in that ſtate called *martial ethiops* by the old chemiſts, poſſeſſing a degree of metallic brilliancy, very friable, and readily reducible into powder, under the hammer, or with a peſtle and mortar. If the experiment has ſucceeded well, from 100 grains of iron will be obtained 135 or 136 grains of ethiops, which is an augmentation of 35 per cent.

If all the attention has been paid to this experiment which it deſerves, the air will be found diminiſhed in weight exactly equal to what the iron has gained. Having therefore burnt 100 grains of iron, which has acquired an additional weight of 35 grains, the diminution of air will be found exactly 70 cubical inches; and it will be found, in the ſequel, that the weight of vital air is pretty nearly half a grain for each cubical inch; ſo that, in effect, the augmentation of weight in the one exactly coincides with the loſs of it in the other.

I ſhall obſerve here, once for all, that, in every experiment of this kind, the preſſure and temperature of the air, both before and after the experiment, muſt be reduced, by calculation, to a common ſtandard of 10° (54.5°) of the thermometer, and 28 inches of the barometer.

ter. Towards the end of this work, the manner of performing this very neceſſary reduction will be found accurately detailed.

If it be required to examine the nature of the air which remains after this experiment, we muſt operate in a ſomewhat different manner. After the combuſtion is finiſhed, and the veſſels have cooled, we firſt take out the cup, and the burnt iron, by introducing the hand through the quickſilver, under the bell-glaſs; we next introduce ſome ſolution of potaſh, or cauſtic alkali, or of the ſulphuret of potaſh, or ſuch other ſubſtance as is judged proper for examining their action upon the reſiduum of air. I ſhall, in the ſequel, give an account of theſe methods of analyſing air, when I have explained the nature of theſe different ſubſtances, which are only here in a manner accidentally mentioned. After this examination, ſo much water muſt be let into the glaſs as will diſplace the quickſilver, and then, by means of a ſhallow diſh placed below the bell-glaſs, it is to be removed into the common water pneumato-chemical apparatus, where the air remaining may be examined at large, and with great facility.

When very ſoft and very pure iron has been employed in this experiment, and, if the combuſtion has been performed in the pureſt reſpirable or vital air, free from all admixture of the noxious or mephitic part, the air which remains

after

after the combuſtion will be found as pure as it was before; but it is difficult to find iron entirely free from a ſmall portion of charry matter, which is chiefly abundant in ſteel. It is likewiſe exceedingly difficult to procure the pure air perfectly free from ſome admixture of mephitis, with which it is almoſt always contaminated; but this ſpecies of noxious air does not, in the ſmalleſt degree, diſturb the reſult of the experiment, as it is always found at the end exactly in the ſame proportion as at the beginning.

I mentioned before, that we have two ways of determining the conſtituent parts of atmoſpheric air, the method of analyſis, and that by ſyntheſis. The calcination of mercury has furniſhed us with an example of each of theſe methods, ſince, after having robbed the reſpirable part of its baſe, by means of the mercury, we have reſtored it, ſo as to recompoſe an air preciſely ſimilar to that of the atmoſphere. But we can equally accompliſh this ſynthetic compoſition of atmoſpheric air, by borrowing the materials of which it is compoſed from different kingdoms of nature. We ſhall ſee hereafter that, when animal ſubſtances are diſſolved in the nitric acid, a great quantity of gas is diſengaged, which extinguiſhes light, and is unfit for animal reſpiration, being exactly ſimilar to the noxious or mephitic part of atmoſpheric air. And, if we take 73 parts, by weight, of this e-

laſtic

laſtic fluid, and mix it with 27 parts of highly reſpirable air, procured from calcined mercury, we will form an elaſtic fluid preciſely ſimilar to atmoſpheric air in all its properties.

There are many other methods of ſeparating the reſpirable from the noxious part of the atmoſpheric air, which cannot be taken notice of in this part, without anticipating information, which properly belongs to the ſubſequent chapters. The experiments already adduced may ſuffice for an elementary treatiſe; and, in matters of this nature, the choice of our evidences is of far greater conſequence than their number.

I ſhall cloſe this article, by pointing out the property which atmoſpheric air, and all the known gaſſes, poſſeſs of diſſolving water, which is of great conſequence to be attended to in all experiments of this nature. Mr Sauſſure found, by experiment, that a cubical foot of atmoſpheric air is capable of holding 12 grains of water in ſolution; Other gaſſes, as the carbonic acid, appear capable of diſſolving a greater quantity; but experiments are ſtill wanting by which to determine their ſeveral proportions. This water, held in ſolution by gaſſes, gives riſe to particular phenomena in many experiments, which require great attention, and which has frequently proved the ſource of great errors to chemiſts in determining the reſults of their experiments.

CHAP.

CHAP. IV.

Nomenclature of the ſeveral Conſtituent Parts of Atmoſpheric Air.

HITHERTO I have been obliged to make uſe of circumlocution, to expreſs the nature of the ſeveral ſubſtances which conſtitute our atmoſphere, having proviſionally uſed the terms of *reſpirable* and *noxious*, or *non-reſpirable parts of the air*. But the inveſtigations I mean to undertake require a more direct mode of expreſſion; and, having now endeavoured to give ſimple and diſtinct ideas of the different ſubſtances which enter into the compoſition of the atmoſphere, I ſhall henceforth expreſs theſe ideas by words equally ſimple.

The temperature of our earth being very near to that at which water becomes ſolid, and reciprocally changes from ſolid to fluid, and as this phenomenon takes place frequently under our obſervation, it has very naturally followed, that, in the languages of at leaſt every climate ſubjected to any degree of winter, a term has been uſed for ſignifying water in the ſtate of ſolidity, when deprived of its caloric. The ſame, however, has not been found neceſſary

ſary with reſpect to water reduced to the ſtate of vapour by an additional doſe of caloric; ſince thoſe perſons who do not make a particular ſtudy of objects of this kind, are ſtill ignorant that water, when in a temperature only a little above the boiling heat, is changed into an elaſtic aëriform fluid, ſuſceptible, like all other gaſſes, of being received and contained in veſſels, and preſerving its gaſſeous form ſo long as it remains at the temperature of 80° (212°), and under a preſſure not exceeding 28 inches of the mercurial barometer. As this phenomenon has not been generally obſerved, no language has uſed a particular term for expreſſing water in this ſtate *; and the ſame thing occurs with all fluids, and all ſubſtances, which do not evaporate in the common temperature, and under the uſual preſſure of our atmoſphere.

For ſimilar reaſons, names have not been given to the liquid or concrete ſtates of moſt of the aëriform fluids: Theſe were not known to ariſe from the combination of caloric with certain baſes; and, as they had not been ſeen either in the liquid or ſolid ſtates, their exiſtence, under theſe forms, was even unknown to natural philoſophers.

---

* In Engliſh, the word *ſteam* is excluſively appropriated to water in the ſtate of vapour. E.

We have not pretended to make any alteration upon ſuch terms as are ſanctified by ancient cuſtom; and, therefore, continue to uſe the words *water* and *ice* in their common acceptation: We likewiſe retain the word *air*, to expreſs that collection of elaſtic fluids which compoſes our atmoſphere; but we have not thought it neceſſary to preſerve the ſame reſpect for modern terms, adopted by latter philoſophers, having conſidered ourſelves as at liberty to reject ſuch as appeared liable to occaſion erroneous ideas of the ſubſtances they are meant to expreſs, and either to ſubſtitute new terms, or to employ the old ones, after modifying them in ſuch a manner as to convey more determinate ideas. New words have been drawn, chiefly from the Greek language, in ſuch a manner as to make their etymology convey ſome idea of what was meant to be repreſented; and theſe we have always endeavoured to make ſhort, and of ſuch a nature as to be changeable into adjectives and verbs.

Following theſe principles, we have, after Mr Macquer's example, retained the term *gas*, employed by Vanhelmont, having arranged the numerous claſs of elaſtic aëriform fluids under that name, excepting only atmoſpheric air. *Gas*, therefore, in our nomenclature, becomes a generic term, expreſſing the fulleſt degree of ſaturation in any body with caloric; being, in fact,

fact, a term expreſſive of a mode of exiſtence. To diſtinguiſh each ſpecies of gas, we employ a ſecond term from the name of the baſe, which, ſaturated with caloric, forms each particular gas. Thus, we name water combined to ſaturation with caloric, ſo as to form an elaſtic fluid, *aqueous gas*; ether, combined in the ſame manner, *etherial gas*; the combination of alkohol with caloric, becomes *alkoholic gas*; and, following the ſame principles, we have *muriatic acid gas*, *ammoniacal gas*, and ſo on of every ſubſtance ſuſceptible of being combined with caloric, in ſuch a manner as to aſſume the gaſſeous or elaſtic aëriform ſtate.

We have already ſeen, that the atmoſpheric air is compoſed of two gaſſes, or aëriform fluids, one of which is capable, by reſpiration, of contributing to animal life, and in which metals are calcinable, and combuſtible bodies may burn; the other, on the contrary, is endowed with directly oppoſite qualities; it cannot be breathed by animals, neither will it admit of the combuſtion of inflammable bodies, nor of the calcination of metals. We have given to the baſe of the former, or reſpirable portion of the air, the name of *oxygen*, from οξυς, *acidum*, and γεινομαι, *gignor*; becauſe, in reality, one of the moſt general properties of this baſe is to form acids, by combining with many different ſubſtances. The union of this baſe with caloric we term *oxygen gas*, which is the ſame with what was formerly called *pure*, or *vital air*. The weight of this gas, at the temperature of 10° (54.50), and under a preſſure equal to 28 inches of the barometer, is half a grain for each cubical inch, or one ounce and a half to each cubical foot.

The chemical properties of the noxious portion of atmoſpheric air being hitherto but little known, we have been ſatisfied to derive the name of its baſe from its known quality of killing ſuch animals as are forced to breathe it, giving it the name of *azote*, from the Greek privitive particle α and ζωὴ, *vita;* hence the name of the noxious part of atmoſpheric air is *azotic gas;* the weight of which, in the ſame temperature, and under the ſame preſſure, is 1 *oz.* 2 *gros.* and 48 *grs.* to the cubical foot, or 0.4444 of a grain to the cubical inch. We cannot deny that this name appears ſomewhat extraordinary; but this muſt be the caſe with all new terms, which cannot be expected to become familiar until they have been ſome time in uſe. We long endeavoured to find a more proper deſignation without ſucceſs; it was at firſt propoſed to call it *alkaligen gas*, as, from the experiments of Mr Berthollet, it appears to enter into the compoſition of ammoniac, or volatile alkali; but then, we have as yet no proof of its making one of the conſtituent elements of

the

the other alkalies; beſide, it is proved to compoſe a part of the nitric acid, which gives as good reaſon to have called it *nitrigen*. For theſe reaſons, finding it neceſſary to reject any name upon ſyſtematic principles, we have conſidered that we run no riſk of miſtake in adopting the terms of *azote*, and *azotic gas*, which only expreſs a matter of fact, or that property which it poſſeſſes, of depriving ſuch animals as breathe it of their lives.

I ſhould anticipate ſubjects more properly reſerved for the ſubſequent chapters, were I in this place to enter upon the nomenclature of the ſeveral ſpecies of gaſſes: It is ſufficient, in this part of the work, to eſtabliſh the principles upon which their denominations are founded. The principal merit of the nomenclature we have adopted is, that, when once the ſimple elementary ſubſtance is diſtinguiſhed by an appropriate term, the names of all its compounds derive readily, and neceſſarily, from this firſt denomination.

CHAP. V.

Of the Decompoſition of Oxygen Gas by Sulphur, Phoſphorus, and Charcoal—and of the Formation of Acids in general.

IN performing experiments, it is a neceſſary principle, which ought never to be deviated from, that they be ſimplified as much as poſſible, and that every circumſtance capable of rendering their reſults complicated be carefully removed. Wherefore, in the experiments which form the object of this chapter, we have never employed atmoſpheric air, which is not a ſimple ſubſtance. It is true, that the azotic gas, which forms a part of its mixture, appears to be merely paſſive during combuſtion and calcination; but, beſides that it retards theſe operations very conſiderably, we are not certain but it may even alter their reſults in ſome circumſtances; for which reaſon, I have thought it neceſſary to remove even this poſſible cauſe of doubt, by only making uſe of pure oxygen gas in the following experiments, which ſhow the effects produced by combuſtion in that gas; and I ſhall advert to ſuch differences as take place in the reſults of theſe, when the oxygen gas, or pure vital

vital air, is mixed, in different proportions, with azotic gas.

Having filled a bell-glaſs (A. Pl. iv. fig. 3), of between five and ſix pints meaſure, with oxygen gas, I removed it from the water trough, where it was filled, into the quickſilver bath, by means of a ſhallow glaſs diſh ſlipped underneath, and having dried the mercury, I introduced 61¼ grains of Kunkel's phoſphorus in two little China cups, like that repreſented at D, fig. 3. under the glaſs A; and that I might ſet fire to each of the portions of phoſphorus ſeparately, and to prevent the one from catching fire from the other, one of the diſhes was covered with a piece of flat glaſs. I next raiſed the quickſilver in the bell-glaſs up to E F, by ſucking out a ſufficient portion of the gas by means of the ſyphon G H I. After this, by means of the crooked iron wire (fig. 16.), made red hot, I ſet fire to the two portions of phoſphorus ſucceſſively, firſt burning that portion which was not covered with the piece of glaſs. The combuſtion was extremely rapid, attended with a very brilliant flame, and conſiderable diſengagement of light and heat. In conſequence of the great heat induced, the gas was at firſt much dilated, but ſoon after the mercury returned to its level, and a conſiderable abſorption of gas took place; at the ſame time, the whole

whole inſide of the glaſs became covered with white light flakes of concrete phoſphoric acid.

At the beginning of the experiment, the quantity of oxygen gas, reduced, as above directed, to a common ſtandard, amounted to 162 cubical inches; and, after the combuſtion was finiſhed, only 23¼ cubical inches, likewiſe reduced to the ſtandard, remained; ſo that the quantity of oxygen gas abſorbed during the combuſtion was 138¾ cubical inches, equal to 69.375 grains.

A part of the phoſphorus remained unconſumed in the bottom of the cups, which being waſhed on purpoſe to ſeparate the acid, weighed about 16¼ grains; ſo that about 45 grains of phoſphorus had been burned: But, as it is hardly poſſible to avoid an error of one or two grains, I leave the quantity ſo far qualified. Hence, as nearly 45 grains of phoſphorus had, in this experiment, united with 69.375 grains of oxygen, and as no gravitating matter could have eſcaped through the glaſs, we have a right to conclude, that the weight of the ſubſtance reſulting from the combuſtion in form of white flakes, muſt equal that of the phoſphorus and oxygen employed, which amounts to 114.375 grains. And we ſhall preſently find, that theſe flakes conſiſted entirely of a ſolid or concrete acid. When we reduce theſe weights to hundredth parts, it will be found, that 100 parts of phoſphorus

phoſphorus require 154 parts of oxygen for ſaturation, and that this combination will produce 254 parts of concrete phoſphoric acid, in form of white fleecy flakes.

This experiment proves, in the moſt convincing manner, that, at a certain degree of temperature, oxygen poſſeſſes a ſtronger elective attraction, or affinity, for phoſphorus than for caloric; that, in conſequence of this, the phoſphorus attracts the baſe of oxygen gas from the caloric, which, being ſet free, ſpreads itſelf over the ſurrounding bodies. But, though this experiment be ſo far perfectly concluſive, it is not ſufficiently rigorous, as, in the apparatus deſcribed, it is impoſſible to aſcertain the weight of the flakes of concrete acid which are formed; we can therefore only determine this by calculating the weights of oxygen and phoſphorus employed; but as, in phyſics, and in chemiſtry, it is not allowable to ſuppoſe what is capable of being aſcertained by direct experiment, I thought it neceſſary to repeat this experiment, as follows, upon a larger ſcale, and by means of a different apparatus.

I took a large glaſs baloon (A. Pl. iv. fig. 4.) with an opening three inches diameter, to which was fitted a cryſtal ſtopper ground with emery, and pierced with two holes for the tubes yyy, xxx. Before ſhutting the baloon with its ſtopper, I introduced the ſupport BC, ſurmounted by the china cup D, containing 150 *grs.* of phoſphorus; the ſtopper was then fitted to the opening of the baloon, luted with fat lute, and covered with ſlips of linen ſpread with quicklime and white of eggs: When the lute was perfectly dry, the weight of the whole apparatus was determined to within a grain, or a grain and a half. I next exhauſted the baloon, by means of an air pump applied to the tube xxx, and then introduced oxygen gas by means of the tube yyy, having a ſtop cock adapted to it. This kind of experiment is moſt readily and moſt exactly performed by means of the hydro-pneumatic machine deſcribed by Mr Meuſnier and me in the Memoirs of the Academy for 1782, pag. 466. and explained in the latter part of this work, with ſeveral important additions and corrections ſince made to it by Mr Meuſnier. With this inſtrument we can readily aſcertain, in the moſt exact manner, both the quantity of oxygen gas introduced into the baloon, and the quantity conſumed during the courſe of the experiment.

When all things were properly diſpoſed, I ſet fire to the phoſphorus with a burning glaſs. The combuſtion was extremely rapid, accompanied with a bright flame, and much heat; as the operation went on, large quantities of white flakes attached themſelves to the inner ſurface of the baloon, ſo that at laſt it was rendered quite

quite opake. The quantity of theſe flakes at laſt became ſo abundant, that, although freſh oxygen gas was continually ſupplied, which ought to have ſupported the combuſtion, yet the phoſphorus was ſoon extinguiſhed. Having allowed the apparatus to cool completely, I firſt aſcertained the quantity of oxygen gas employed, and weighed the baloon accurately, before it was opened. I next waſhed, dried, and weighed the ſmall quantity of phoſphorus remaining in the cup, on purpoſe to determine the whole quantity of phoſphorus conſumed in the experiment; this reſiduum of the phoſphorus was of a yellow ochrey colour. It is evident, that by theſe ſeveral precautions, I could eaſily determine, 1ſt, the weight of the phoſphorus conſumed; 2d, the weight of the flakes produced by the combuſtion; and, 3d, the weight of the oxygen which had combined with the phoſphorus. This experiment gave very nearly the ſame reſults with the former, as it proved that the phoſphorus, during its combuſtion, had abſorbed a little more than one and a half its weight of oxygen; and I learned with more certainty, that the weight of the new ſubſtance, produced in the experiment, exactly equalled the ſum of the weights of the phoſphorus conſumed, and oxygen abſorbed, which indeed was eaſily determinable *a priori*. If the oxygen gas employed be pure, the reſiduum after combuſtion

tion is as pure as the gas employed; this proves that nothing eſcapes from the phoſphorus, capable of altering the purity of the oxygen gas, and that the only action of the phoſphorus is to ſeparate the oxygen from the caloric, with which it was before united.

I mentioned above, that when any combuſtible body is burnt in a hollow ſphere of ice, or in an apparatus properly conſtructed upon that principle, the quantity of ice melted during the combuſtion is an exact meaſure of the quantity of caloric diſengaged. Upon this head, the memoir given by M. de la Place and me, A°. 1780, p. 355, may be conſulted. Having ſubmitted the combuſtion of phoſphorus to this trial, we found that one pound of phoſphorus melted a little more than 100 pounds of ice during its combuſtion.

The combuſtion of phoſphorus ſucceeds equally well in atmoſpheric air as in oxygen gas, with this difference, that the combuſtion is vaſtly ſlower, being retarded by the large proportion of azotic gas mixed with the oxygen gas, and that only about one-fifth part of the air employed is abſorbed, becauſe as the oxygen gas only is abſorbed, the proportion of the azotic gas becomes ſo great toward the cloſe of the experiment, as to put an end to the combuſtion.

I have already ſhown, that phoſphorus is changed by combuſtion into an extremely light, white, flakey matter; and its properties are entirely altered by this transformation: From being inſoluble in water, it becomes not only ſoluble, but ſo greedy of moiſture, as to attract the humidity of the air with aſtoniſhing rapidity; by this means it is converted into a liquid, conſiderably more denſe, and of more ſpecific gravity than water. In the ſtate of phoſphorus before combuſtion, it had ſcarcely any ſenſible taſte, by its union with oxygen it acquires an extremely ſharp and ſour taſte: in a word, from one of the claſs of combuſtible bodies, it is changed into an incombuſtible ſubſtance, and becomes one of thoſe bodies called acids.

This property of a combuſtible ſubſtance to be converted into an acid, by the addition of oxygen, we ſhall preſently find belongs to a great number of bodies: Wherefore, ſtrict logic requires that we ſhould adopt a common term for indicating all theſe operations which produce analogous reſults; this is the true way to ſimplify the ſtudy of ſcience, as it would be quite impoſſible to bear all its ſpecifical details in the memory, if they were not claſſically arranged. For this reaſon, we ſhall diſtinguiſh this converſion of phoſphorus into an acid, by its union with oxygen, and in general every combination of oxygen with a combuſtible ſubſtance,

ſtance, by the term of *oxygenation:* from which I ſhall adopt the verb to *oxygenate*, and of conſequence ſhall ſay, that in *oxygenating* phoſphorus we convert it into an acid.

Sulphur is likewiſe a combuſtible body, or, in other words, it is a body which poſſeſſes the power of decompoſing oxygen gas, by attracting the oxygen from the caloric with which it was combined. This can very eaſily be proved, by means of experiments quite ſimilar to thoſe we have given with phoſphorus; but it is neceſſary to premiſe, that in theſe operations with ſulphur, the ſame accuracy of reſult is not to be expected as with phoſphorus; becauſe the acid which is formed by the combuſtion of ſulphur is difficultly condenſible, and becauſe ſulphur burns with more difficulty, and is ſoluble in the different gaſſes. But I can ſafely aſſert, from my own experiments, that ſulphur in burning abſorbs oxygen gas; that the reſulting acid is conſiderably heavier than the ſulphur burnt; that its weight is equal to the ſum of the weights of the ſulphur which has been burnt, and of the oxygen abſorbed; and, laſtly, that this acid is weighty, incombuſtible, and miſcible with water in all proportions: The only uncertainty remaining upon this head, is with regard to the proportions of ſulphur and of oxygen which enter into the compoſition of the acid.

Charcoal, which, from all our preſent knowledge regarding it, muſt be conſidered as a ſimple combuſtible body, has likewiſe the property of decompoſing oxygen gas, by abſorbing its baſe from the caloric: But the acid reſulting from this combuſtion does not condenſe in the common temperature; under the preſſure of our atmoſphere, it remains in the ſtate of gas, and requires a large proportion of water to combine with or be diſſolved in. This acid has, however, all the known properties of other acids, though in a weaker degree, and combines, like them, with all the baſes which are ſuſceptible of forming neutral ſalts.

The combuſtion of charcoal in oxygen gas, may be effected like that of phoſphorus in the bell-glaſs, (A. Pl. IV. fig. 3.) placed over mercury: but, as the heat of red hot iron is not ſufficient to ſet fire to the charcoal, we muſt add a ſmall morſel of tinder, with a minute particle of phoſphorus, in the ſame manner as directed in the experiment for the combuſtion of iron. A detailed account of this experiment will be found in the memoirs of the academy for 1781, p. 448. By that experiment it appears, that 28 parts by weight of charcoal require 72 parts of oxygen for ſaturation, and that the aëriform acid produced is preciſely equal in weight to the ſum of the weights of the charcoal and oxygen gas employed.

ployed. This aëriform acid was called fixed or fixable air by the chemiſts who firſt diſcovered it; they did not then know whether it was air reſembling that of the atmoſphere, or ſome other elaſtic fluid, vitiated and corrupted by combuſtion; but ſince it is now aſcertained to be an acid, formed like all others by the oxygenation of its peculiar baſe, it is obvious that the name of fixed air is quite ineligible*.

By burning charcoal in the apparatus mentioned p. 60, Mr de la Place and I found that one *lib.* of charcoal melted 96 *libs.* 6 *oz.* of ice; that, during the combuſtion, 2 *libs.* 9 *oz.* 1 *gros.* 10 *grs.* of oxygen were abſorbed, and that 3 *libs.* 9 *oz.* 1 *gros.* 10 *grs.* of acid gas were formed. This gas weighs 0.695 parts of a grain for each cubical inch, in the common ſtandard temperature and preſſure mentioned above, ſo that 34,242 cubical inches of acid gas are produced by the combuſtion of one pound of charcoal.

I might multiply theſe experiments, and ſhow by a numerous ſucceſſion of facts, that all acids are formed by the combuſtion of certain ſubſtances; but I am prevented from doing ſo in this

---

* It may be proper to remark, though here omitted by the author, that, in conformity with the general principles of the new nomenclature, this acid is by Mr Lavoiſier and his coleagues called the carbonic acid, and when in the aëriform ſtate carbonic acid gas. E.

place, by the plan which I have laid down, of proceeding only from facts already aſcertained, to ſuch as are unknown, and of drawing my examples only from circumſtances already explained. In the mean time, however, the three examples above cited may ſuffice for giving a clear and accurate conception of the manner in which acids are formed. By theſe it may be clearly ſeen, that oxygen is an element common to them all, which conſtitutes their acidity; and that they differ from each other, according to the nature of the oxygenated or acidified ſubſtance. We muſt therefore, in every acid, carefully diſtinguiſh between the acidifiable, baſe, which Mr de Morveau calls the radical, and the acidifiing principle or oxygen.

CHAP. VI.

Of the Nomenclature of Acids in general, and particularly of thoſe drawn from Nitre and Sea-Salt.

IT becomes extremely eaſy, from the principles laid down in the preceding chapter, to eſtabliſh a ſyſtematic nomenclature for the acids: The word *acid*, being uſed as a generic term, each acid falls to be diſtinguiſhed in language, as in nature, by the name of its baſe or radical. Thus, we give the generic name of acids to the products of the combuſtion or oxygenation of phoſphorus, of ſulphur, and of charcoal; and theſe products are reſpectively named, the *phoſphoric acid*, the *ſulphuric acid*, and the *carbonic acid.*

There is, however, a remarkable circumſtance in the oxygenation of combuſtible bodies, and of a part of ſuch bodies as are convertible into acids, that they are ſuſceptible of different degrees of ſaturation with oxygen, and that the reſulting acids, though formed by the union of the ſame elements, are poſſeſſed of different properties, depending upon that difference of proportion. Of this, the phoſphoric acid, and more eſpecially the ſulphuric, furniſhes us with examples.

amples. When ſulphur is combined with a ſmall proportion of oxygen, it forms, in this firſt or lower degree of oxygenation, a volatile acid, having a penetrating odour, and poſſeſſed of very particular qualities. By a larger proportion of oxygen, it is changed into a fixed, heavy acid, without any odour, and which, by combination with other bodies, gives products quite different from thoſe furniſhed by the former. In this inſtance, the principles of our nomenclature ſeem to fail; and it ſeems difficult to derive ſuch terms from the name of the acidifiable baſe, as ſhall diſtinctly expreſs theſe two degrees of ſaturation, or oxygenation, without circumlocution. By reflection, however, upon the ſubject, or perhaps rather from the neceſſity of the caſe, we have thought it allowable to expreſs theſe varieties in the oxygenation of the acids, by ſimply varying the termination of their ſpecific names. The volatile acid produced from ſulphur was anciently known to Stahl under the name of *ſulphurous* acid [*]. We have pre-

---

[*] The term formerly uſed by the Engliſh chemiſts for this acid was written *ſulphureous*; but we have thought proper to ſpell it as above, that it may better conform with the ſimilar terminations of nitrous, carbonous, &c. to be uſed hereafter. In general, we have uſed the Engliſh terminations *ic* and *ous* to tranſlate the terms of the Author which end with *ique* and *eux*, with hardly any other alterations.—E.

preſerved that term for this acid from ſulphur under-ſaturated with oxygen; and diſtinguiſh the other, or completely ſaturated or oxygenated acid, by the name of *ſulphuric* acid. We ſhall therefore ſay, in this new chemical language, that ſulphur, in combining with oxygen, is ſuſceptible of two degrees of ſaturation; that the firſt, or leſſer degree, conſtitutes ſulphurous acid, which is volatile and penetrating; whilſt the ſecond, or higher degree of ſaturation, produces ſulphuric acid, which is fixed and inodorous. We ſhall adopt this difference of termination for all the acids which aſſume ſeveral degrees of ſaturation. Hence we have a phoſphorous and a phoſphoric acid, an acetous and an acetic acid; and ſo on, for others in ſimilar circumſtances.

This part of chemical ſcience would have been extremely ſimple, and the nomenclature of the acids would not have been at all perplexed, as it is now in the old nomenclature, if the baſe or radical of each acid had been known when the acid itſelf was diſcovered. Thus, for inſtance, phoſphorus being a known ſubſtance before the diſcovery of its acid, this latter was rightly diſtinguiſhed by a term drawn from the name of its acidifiable baſe. But when, on the contrary, an acid happened to be diſcovered before its baſe, or rather, when the acidifiable baſe from which it was formed remained unknown, names were adopted for the two, which have not the ſmalleſt connection; and thus, not only the memory became burthened with uſeleſs appellations, but even the minds of ſtudents, nay even of experienced chemiſts, became filled with falſe ideas, which time and reflection alone is capable of eradicating. We may give an inſtance of this confuſion with reſpect to the acid ſulphur: The former chemiſts having procured this acid from the vitriol of iron, gave it the name of the vitriolic acid from the name of the ſubſtance which produced it; and they were then ignorant that the acid procured from ſulphur by combuſtion was exactly the ſame.

The ſame thing happened with the aeriform acid formerly called *fixed air*; it not being known that this acid was the reſult of combining charcoal with oxygen, a variety of denominations have been given to it, not one of which conveys juſt ideas of its nature or origin. We have found it extremely eaſy to correct and modify the ancient language with reſpect to theſe acids proceeding from known baſes, having converted the name of *vitriolic acid* into that of *ſulphuric*, and the name of *fixed air* into that of *carbonic acid*; but it is impoſſible to follow this plan with the acids whoſe baſes are ſtill unknown; with theſe we have been obliged to uſe a contrary plan, and, inſtead of forming the name of the acid from that of its baſe,

baſe, have been forced to denominate the unknown baſe from the name of the known acid, as happens in the caſe of the acid which is procured from ſea-ſalt.

To diſengage this acid from the alkaline baſe with which it is combined, we have only to pour ſulphuric acid upon ſea-ſalt, immediately a briſk effervefcence takes place, white vapours ariſe, of a very penetrating odour, and, by only gently heating the mixture, all the acid is driven off. As, in the common temperature and preſſure of our atmoſphere, this acid is naturally in the ſtate of gas, we muſt uſe particular precautions for retaining it in proper veſſels. For ſmall experiments, the moſt ſimple and moſt commodious apparatus conſiſts of a ſmall retort G, (Pl. V. Fig. 5.), into which the ſea-ſalt is introduced, well dried *, we then pour on ſome concentrated ſulphuric acid, and immediately introduce the beak of the retort under little jars or bell-glaſſes A, (ſame Plate and Fig.). previouſly filled with quickſilver. In proportion as the acid gas is diſengaged, it paſſes into the jar, and gets to the top of the quickſilver, which it diſplaces. When the diſengagement of

---

* For this purpoſe, the operation called *decrepitation* is uſed, which conſiſts in ſubjecting it to nearly a red heat, in a proper veſſel, ſo as to evaporate all its water of cryſtallization.—E.

of the gas ſlackens, a gentle heat is applied to the retort, and gradually increaſed till nothing more paſſes over. This acid gas has a very ſtrong affinity with water, which abſorbs an enormous quantity of it, as is proved by introducing a very thin layer of water into the glaſs which contains the gas; for, in an inſtant, the whole acid gas diſappears, and combines with the water.

This latter circumſtance is taken advantage of in laboratories and manufactures, on purpoſe to obtain the acid of ſea-ſalt in a liquid form; and for this purpoſe the apparatus (Pl. IV. Fig. 1.) is employed. It conſiſts, 1ſt, of a tubulated retort A, into which the ſea-ſalt, and after it the ſulphuric acid, are introduced through the opening H; 2d, of the baloon or recipient *c*, *b*, intended for containing the ſmall quantity of liquid which paſſes over during the proceſs; and, 3d, of a ſet of bottles, with two mouths, L, L, L, L, half filled with water, intended for abſorbing the gas diſengaged by the diſtillation. This apparatus will be more amply deſcribed in the latter part of this work.

Although we have not yet been able, either to compoſe or to decompound this acid of ſea-ſalt, we cannot have the ſmalleſt doubt that it, like all other acids, is compoſed by the union of oxygen with an acidifiable baſe. We have therefore called this unknown ſubſtance the *muriatic baſe*, or *muriatic radical*, deriving this name, after the example of Mr Bergman and Mr de Morveau, from the Latin word *muria*, which was anciently uſed to ſignify ſea-ſalt. Thus, without being able exactly to determine the component parts of *muriatic acid*, we deſign, by that term, a volatile acid, which retains the form of gas in the common temperature and preſſure of our atmoſphere, which combines with great facility, and in great quantity, with water, and whoſe acidifiable baſe adheres ſo very intimately with oxygen, that no method has hitherto been deviſed for ſeparating them. If ever this acidifiable baſe of the muriatic acid is diſcovered to be a known ſubſtance, though now unknown in that capacity, it will be requiſite to change its preſent denomination for one analogous with that of its baſe.

In common with ſulphuric acid, and ſeveral other acids, the muriatic is capable of different degrees of oxygenation; but the exceſs of oxygen produces quite contrary effects upon it from what the ſame circumſtance produces upon the acid of ſulphur. The lower degree of oxygenation converts ſulphur into a volatile gaſſeous acid, which only mixes in ſmall proportions with water, whilſt a higher oxygenation forms an acid poſſeſſing much ſtronger acid properties, which is very fixed and cannot remain in the ſtate of gas but in a very high temperature, which has no ſmell, and which mixes in large proportion with water. With muriatic acid, the direct reverſe takes place; an additional ſaturation with oxygen renders it more volatile, of a more penetrating odour, leſs miſcible with water, and diminiſhes its acid properties. We were at firſt inclined to have denominated theſe two degrees of ſaturation in the ſame manner as we had done with the acid of ſulphur, calling the leſs oxygenated *muriatous acid*, and that which is more ſaturated with oxygen *muriatic acid*: But, as this latter gives very particular reſults in its combinations, and as nothing analogous to it is yet known in chemiſtry, we have left the name of muriatic acid to the leſs ſaturated, and give the latter the more compounded appellation of *oxygenated muriatic acid*.

Although the baſe or radical of the acid which is extracted from nitre or ſaltpetre be better known, we have judged proper only to modify its name in the ſame manner with that of the muriatic acid. It is drawn from nitre, by the intervention of ſulphuric acid, by a proceſs ſimilar to that deſcribed for extracting the muriatic acid, and by means of the ſame apparatus (Pl. IV. Fig. 1.). In proportion as the acid paſſes over, it is in part condenſed in the baloon or recipient, and the reſt is abſorbed by the water contained in the bottles L, L, L, L; the water becomes firſt green, then blue, and at laſt yellow, in proportion to the concentration of the acid. During this operation, a large quantity of oxygen gas, mixed with a ſmall proportion of azotic gas, is diſengaged.

This acid, like all others, is compoſed of oxygen, united to an acidifiable baſe, and is even the firſt acid in which the exiſtence of oxygen was well aſcertained. Its two conſtituent elements are but weakly united, and are eaſily ſeparated, by preſenting any ſubſtance with which oxygen has a ſtronger affinity than with the acidifiable baſe peculiar to this acid. By ſome experiments of this kind, it was firſt diſcovered that azote, or the baſe of mephitis or azotic gas, conſtituted its acidifiable baſe or radical; and conſequently that the acid of nitre was really an azotic acid, having azote for its baſe, combined with oxygen. For theſe reaſons, that we might be conſiſtent with our principles, it appeared neceſſary, either to call the acid by the name of *azotic*, or to name the baſe *nitric radical;* but from either of theſe we were diſſuaded, by the following conſiderations. In the *firſt* place, it ſeemed difficult to change the name of nitre or ſaltpetre, which has been univerſally adopted in ſociety, in manufactures, and in chemiſtry; and, on the other hand, azote having been diſcovered by Mr Berthollet to be the baſe of volatile alkali, or ammoniac, as well as of this acid,

cid, we thought it improper to call it nitric radical. We have therefore continued the term of azote to the baſe of that part of atmoſpheric air which is likewiſe the nitric and ammoniacal radical; and we have named the acid of nitre, in its lower and higher degrees of oxygenation, *nitrous acid* in the former, and *nitric acid* in the latter ſtate; thus preſerving its former appellation properly modified.

Several very reſpectable chemiſts have diſapproved of this deference for the old terms, and wiſhed us to have perſevered in perfecting a new chemical language, without paying any reſpect for ancient uſage; ſo that, by thus ſteering a kind of middle courſe, we have expoſed ourſelves to the cenſures of one ſect of chemiſts, and to the expoſtulations of the oppoſite party.

The acid of nitre is ſuſceptible of aſſuming a great number of ſeparate ſtates, depending upon its degree of oxygenation, or upon the proportions in which azote and oxygen enter into its compoſition. By a firſt or loweſt degree of oxygenation, it forms a particular ſpecies of gas, which we ſhall continue to name *nitrous gas*; this is compoſed nearly of two parts, by weight, of oxygen combined with one part of azote; and in this ſtate it is not miſcible with water. In this gas, the azote is by no means ſaturated with oxygen, but, on the contrary, has ſtill

ſtill a very great affinity for that element, and even attracts it from atmoſpheric air, immediately upon getting into contact with it. This combination of nitrous gas with atmoſpheric air has even become one of the methods for determining the quantity of oxygen contained in air, and conſequently for aſcertaining its degree of ſalubrity.

This addition of oxygen converts the nitrous gas into a powerful acid, which has a ſtrong affinity with water, and which is itſelf ſuſceptible of various additional degrees of oxygenation. When the proportions of oxygen and azote is below three parts, by weight, of the former, to one of the latter, the acid is red coloured, and emits copious fumes. In this ſtate, by the application of a gentle heat, it gives out nitrous gas; and we term it, in this degree of oxygenation, *nitrous acid*. When four parts, by weight, of oxygen, are combined with one part of azote, the acid is clear and colourleſs, more fixed in the fire than the nitrous acid, has leſs odour, and its conſtituent elements are more firmly united. This ſpecies of acid, in conformity with our principles of nomenclature, is called *nitric acid*.

Thus, nitric acid is the acid of nitre, ſurcharged with oxygen; nitrous acid is the acid of nitre ſurcharged with azote; or, what is the ſame thing, with nitrous gas; and this latter is

azote

azote not ſufficiently ſaturated with oxygen to poſſeſs the properties of an acid. To this degree of oxygenation, we have afterwards, in the courſe of this work, given the generical name of *oxyd* *.

CHAP.

---

* In ſtrict conformity with the principles of the new nomenclature, but which the Author has given his reaſons for deviating from in this inſtance, the following ought to have been the terms for azote, in its ſeveral degrees of oxygenation: Azote, azotic gas, (azote combined with caloric), azotic oxyd gas, nitrous acid, and nitric acid.—E.

CHAP. VII.

Of the Decompoſition of Oxygen Gas by means of Metals, and the Formation of Metallic Oxyds.

OXYGEN has a ſtronger affinity with metals heated to a certain degree than with caloric; in conſequence of which, all metallic bodies, excepting gold, ſilver, and platina, have the property of decompoſing oxygen gas, by attracting its baſe from the caloric with which it was combined. We have already ſhown in what manner this decompoſition takes place, by means of mercury and iron; having obſerved, that, in the caſe of the firſt, it muſt be conſidered as a kind of gradual combuſtion, whilſt, in the latter, the combuſtion is extremely rapid, and attended with a brilliant flame. The uſe of the heat employed in theſe operations is to ſeparate the particles of the metal from each other, and to diminiſh their attraction of coheſion or aggregation, or, what is the ſame thing, their mutual attraction for each other.

The abſolute weight of metallic ſubſtances is augmented in proportion to the quantity of oxygen they abſorb; they, at the ſame time, loſe their metallic ſplendour, and are reduced into an an earthy pulverulent matter. In this ſtate metals muſt not be conſidered as entirely ſaturated with oxygen, becauſe their action upon this element is counterbalanced by the power of affinity between it and caloric. During the calcination of metals, the oxygen is therefore acted upon by two ſeparate and oppoſite powers, that of its attraction for caloric, and that exerted by the metal, and only tends to unite with the latter in conſequence of the exceſs of the latter over the former, which is, in general, very inconſiderable. Wherefore, when metallic ſubſtances are oxygenated in atmoſpheric air, or in oxygen gas, they are not converted into acids like ſulphur, phoſphorus, and charcoal, but are only changed into intermediate ſubſtances, which, though approaching to the nature of ſalts, have not acquired all the ſaline properties. The old chemiſts have affixed the name of *calx* not only to metals in this ſtate, but to every body which has been long expoſed to the action of fire without being melted. They have converted this word *calx* into a generical term, under which they confound calcareous earth, which, from a neutral ſalt, which it really was before calcination, has been changed by fire into an earthy alkali, by *loſing* half of its weight, with metals which, by the ſame means, have joined themſelves to a new ſubſtance, whoſe quantity often *exceeds* half their weight, and by which they

have

have been changed almoſt into the nature of acids. This mode of claſſifying ſubſtances of ſo very oppoſite natures, under the ſame generic name, would have been quite contrary to our principles of nomenclature, eſpecially as, by retaining the above term for this ſtate of metallic ſubſtances, we muſt have conveyed very falſe ideas of its nature. We have, therefore, laid aſide the expreſſion *metallic calx* altogether, and have ſubſtituted in its place the term *oxyd*, from the Greek word οξυς.

By this may be ſeen, that the language we have adopted is both copious and expreſſive. The firſt or loweſt degree of oxygenation in bodies, converts them into *oxyds*; a ſecond degree of additional oxygenation conſtitutes the claſs of acids, of which the ſpecific names, drawn from their particular baſes, terminate in *ous*, as the *nitrous* and *ſulphurous* acids; the third degree of oxygenation changes theſe into the ſpecies of acids diſtinguiſhed by the termination in *ic*, as the *nitric* and *ſulphuric* acids; and, laſtly, we can expreſs a fourth, or higheſt degree of oxygenation, by adding the word *oxygenated* to the name of the acid, as has been already done with the *oxygenated muriatic* acid.

We have not confined the term *oxyd* to expreſſing the combinations of metals with oxygen, but have extended it to ſignify that firſt degree of oxygenation in all bodies, which, without

without converting them into acids, cauſes them to approach to the nature of ſalts. Thus, we give the name of *oxyd of ſulphur* to that ſoft ſubſtance into which ſulphur is converted by incipient combuſtion; and we call the yellow matter left by phoſphorus, after combuſtion, by the name of *oxyd of phoſphorus*. In the ſame manner, nitrous gas, which is azote in its firſt degree of oxygenation, is the *oxyd of azote*. We have likewiſe oxyds in great numbers from the vegetable and animal kingdoms; and I ſhall ſhow, in the ſequel, that this new language throws great light upon all the operations of art and nature.

We have already obſerved, that almoſt all the metallic oxyds have peculiar and permanent colours. Theſe vary not only in the different ſpecies of metals, but even according to the various degrees of oxygenation in the ſame metal. Hence we are under the neceſſity of adding two epithets to each oxyd, one of which indicates the metal *oxydated* *, while the other indicates the

---

* Here we ſee the word *oxyd* converted into the verb *to oxydate, oxydated, oxydating*, after the ſame manner with the derivation of the verb *to oxygenate, oxygenated, oxygenating*, from the word *oxygen*. I am not clear of the abſolute neceſſity of this ſecond verb here firſt introduced, but think, in a work of this nature, that it is the duty of the tranſlator to neglect every other conſideration for the ſake of ſtrict fidelity to the ideas of his author.—E.

the peculiar colour of the oxyd. Thus, we have the black oxyd of iron, the red oxyd of iron, and the yellow oxyd of iron; which expreſſions reſpectively anſwer to the old unmeaning terms of martial ethiops, colcothar, and ruſt of iron, or ochre. We have likewiſe the gray, yellow, and red oxyds of lead, which anſwer to the equally falſe or inſignificant terms, aſhes of lead, maſſicot, and minium.

Theſe denominations ſometimes become rather long, eſpecially when we mean to indicate whether the metal has been oxydated in the air, by detonation with nitre, or by means of acids; but then they always convey juſt and accurate ideas of the correſponding object which we wiſh to expreſs by their uſe. All this will be rendered perfectly clear and diſtinct by means of the tables which are added to this work.

CHAP. VIII.

Of the Radical Principle of Water, and of its Decompoſition by Charcoal and Iron.

UNTIL very lately, water has always been thought a ſimple ſubſtance, inſomuch that the older chemiſts conſidered it as an element. Such it undoubtedly was to them, as they were unable to decompoſe it; or, at leaſt, ſince the decompoſition which took place daily before their eyes was entirely unnoticed. But we mean to prove, that water is by no means a ſimple or elementary ſubſtance. I ſhall not here pretend to give the hiſtory of this recent, and hitherto conteſted diſcovery, which is detailed in the Memoirs of the Academy for 1781, but ſhall only bring forwards the principal proofs of the decompoſition and compoſition of water; and, I may venture to ſay, that theſe will be convincing to ſuch as conſider them impartially.

Experiment Firſt.

Having fixed the glaſs tube EF, (Pl. vii. fig. 11.) of from 8 to 12 lines diameter, acroſs a furnace, with a ſmall inclination from E to F, lute

lute the ſuperior extremity E to the glaſs retort A, containing a determinate quantity of diſtilled water, and to the inferior extremity F, the worm SS fixed into the neck of the doubly tubulated bottle H, which has the bent tube KK adapted to one of its openings, in ſuch a manner as to convey ſuch aëriform fluids or gaſſes as may be diſengaged, during the experiment, into a proper apparatus for determining their quantity and nature.

To render the ſucceſs of this experiment certain, it is neceſſary that the tube EF be made of well annealed and difficultly fuſible glaſs, and that it be coated with a lute compoſed of clay mixed with powdered ſtone-ware; beſides which, it muſt be ſupported about its middle by means of an iron bar paſſed through the furnace, leſt it ſhould ſoften and bend during the experiment. A tube of China-ware, or porcellain, would anſwer better than one of glaſs for this experiment, were it not difficult to procure one ſo entirely free from pores as to prevent the paſſage of air or of vapours.

When things are thus arranged, a fire is lighted in the furnace EFCD, which is ſupported of ſuch a ſtrength as to keep the tube EF red hot, but not to make it melt; and, at the ſame time, ſuch a fire is kept up in the furnace VVXX, as to keep the water in the retort A continually boiling.

In

In proportion as the water in the retort A is evaporated, it fills the tube EF, and drives out the air it contained by the tube KK; the aqueous gas formed by evaporation is condenſed by cooling in the worm SS, and falls, drop by drop, into the tubulated bottle H. Having continued this operation until all the water be evaporated from the retort, and having carefully emptied all the veſſels employed, we find that a quantity of water has paſſed over into the bottle H, exactly equal to what was before contained in the retort A, without any diſengagement of gas whatſoever: So that this experiment turns out to be a ſimple diſtillation; and the reſult would have been exactly the ſame, if the water had been run from one veſſel into the other, through the tube EF, without having undergone the intermediate incandeſcence.

Experiment Second.

The apparatus being diſpoſed, as in the former experiment, 28 *grs.* of charcoal, broken into moderately ſmall parts, and which has previouſly been expoſed for a long time to a red heat in cloſe veſſels, are introduced into the tube EF. Every thing elſe is managed as in the preceding experiment.

The water contained in the retort A is diſtilled, as in the former experiment, and, being

condenſed

condenſed in the worm, falls into the bottle H; but, at the ſame time, a conſiderable quantity of gas is diſengaged, which, eſcaping by the tube KK, is received in a convenient apparatus for that purpoſe. After the operation is finiſhed, we find nothing but a few atoms of aſhes remaining in the tube EF; the 28 *grs.* of charcoal having entirely diſappeared.

When the diſengaged gaſſes are carefully examined, they are found to weigh 113.7 *grs.* *; theſe are of two kinds, viz. 144 cubical inches of carbonic acid gas, weighing 100 *grs.* and 380 cubical inches of a very light gas, weighing only 13.7 *grs.* which takes fire when in contact with air, by the approach of a lighted body; and, when the water which has paſſed over into the bottle H is carefully examined, it is found to have loſt 85.7 *grs.* of its weight. Thus, in this experiment, 85.7 *grs.* of water, joined to 28 *grs.* of charcoal, have combined in ſuch a way as to form 100 *grs.* of carbonic acid, and 13.7 *grs.* of a particular gas capable of being burnt.

I have already ſhown, that 100 *grs.* of carbonic acid gas conſiſts of 72 *grs.* of oxygen, combined with 28 *grs.* of charcoal; hence the 28 *grs.*

---

* In the latter part of this work will be found a particular account of the proceſſes neceſſary for ſeparating the different kinds of gaſſes, and for determining their quantities.—A.

grs. of charcoal placed in the glaſs tube have acquired 72 *grs.* of oxygen from the water; and it follows, that 85.7 *grs.* of water are compoſed of 72 *grs.* of oxygen, combined with 13.7 *grs.* of a gas ſuſceptible of combuſtion. We ſhall ſee preſently that this gas cannot poſſibly have been diſengaged from the charcoal, and muſt, conſequently, have been produced from the water.

I have ſuppreſſed ſome circumſtances in the above account of this experiment, which would only have complicated and obſcured its reſults in the minds of the reader. For inſtance, the inflammable gas diſſolves a very ſmall part of the charcoal, by which means its weight is ſomewhat augmented, and that of the carbonic gas proportionally diminiſhed. Altho' the alteration produced by this circumſtance is very inconſiderable; yet I have thought it neceſſary to determine its effects by rigid calculation, and to report, as above, the reſults of the experiment in its ſimplified ſtate, as if this circumſtance had not happened. At any rate, ſhould any doubts remain reſpecting the conſequences I have drawn from this experiment, they will be fully diſſipated by the following experiments, which I am going to adduce in ſupport of my opinion.

Experiment Third.

The apparatus being diſpoſed exactly as in the former experiment, with this difference, that inſtead of the 28 *grs.* of charcoal, the tube EF is filled with 274 *grs.* of ſoft iron in thin plates, rolled up ſpirally. The tube is made red hot by means of its furnace, and the water in the retort A is kept conſtantly boiling till it be all evaporated, and has paſſed through the tube EF, ſo as to be condenſed in the bottle H.

No carbonic acid gas is diſengaged in this experiment, inſtead of which we obtain 416 cubical inches, or 15 *grs.* of inflammable gas, thirteen times lighter than atmoſpheric air. By examining the water which has been diſtilled, it is found to have loſt 100 *grs.* and the 274 *grs.* of iron confined in the tube are found to have acquired 85 *grs.* additional weight, and its magnitude is conſiderably augmented. The iron is now hardly at all attractable by the magnet; it diſſolves in acids without efferveſcence; and, in ſhort, it is converted into a black oxyd, preciſely ſimilar to that which has been burnt in oxygen gas.

In this experiment we have a true *oxydation* of iron, by means of water, exactly ſimilar to that produced in air by the aſſiſtance of heat. One hundred grains of water having been decompoſed,

compoſed, 85 *grs.* of oxygen have combined with the iron, ſo as to convert it into the ſtate of black oxyd, and 15 *grs.* of a peculiar inflammable gas are diſengaged: From all this it clearly follows, that water is compoſed of oxygen combined with the baſe of an inflammable gas, in the reſpective proportions of 85 parts, by weight of the former, to 15 parts of the latter.

Thus water, beſides the oxygen, which is one of its elements in common with many other ſubſtances, contains another element as its conſtituent baſe or radical, and for which we muſt find an appropriate term. None that we could think of ſeemed better adapted than the word *hydrogen*, which ſignifies the *generative principle of water*, from ὑδορ *aqua*, and γεινομαι *gignor* *. We call the combination of this element with caloric *hydrogen gas;* and the term hydrogen expreſſes the baſe of that gas, or the radical of water.

---

* This expreſſion Hydrogen has been very ſeverely criticiſed by ſome, who pretend that it ſignifies engendered by water, and not that which engenders water. The experiments related in this chapter prove, that, when water is decompoſed, hydrogen is produced, and that, when hydrogen is combined with oxygen, water is produced: So that we may ſay, with equal truth, that water is produced from hydrogen, or hydrogen is produced from water.—A.

This experiment furniſhes us with a new combuſtible body, or, in other words, a body which has ſo much affinity with oxygen as to draw it from its connection with caloric, and to decompoſe air or oxygen gas. This combuſtible body has itſelf ſo great affinity with caloric, that, unleſs when engaged in a combination with ſome other body, it always ſubſiſts in the aëriform or gaſſeous ſtate, in the uſual temperature and preſſure of our atmoſphere. In this ſtate of gas it is about $\frac{1}{13}$ of the weight of an equal bulk of atmoſpheric air; it is not abſorbed by water, though it is capable of holding a ſmall quantity of that fluid in ſolution, and it is incapable of being uſed for reſpiration.

As the property this gas poſſeſſes, in common with all other combuſtible bodies, is nothing more than the power of decompoſing air, and carrying off its oxygen from the caloric with which it was combined, it is eaſily underſtood that it cannot burn, unleſs in contact with air or oxygen gas. Hence, when we ſet fire to a bottle full of this gas, it burns gently, firſt at the neck of the bottle, and then in the inſide of it, in proportion as the external air gets in: This combuſtion is ſlow and ſucceſſive, and only takes place at the ſurface of contact between the two gaſſes. It is quite different when the two gaſſes are mixed before they are ſet on fire: If, for inſtance, after having introduced one part of oxygen

oxygen gas into a narrow mouthed bottle, we fill it up with two parts of hydrogen gas, and bring a lighted taper, or other burning body, to the mouth of the bottle, the combuſtion of the two gaſſes takes place inſtantaneouſly with a violent exploſion. This experiment ought only to be made in a bottle of very ſtrong green glaſs, holding not more than a pint, and wrapped round with twine, otherwiſe the operator will be expoſed to great danger from the rupture of the bottle, of which the fragments will be thrown about with great force.

If all that has been related above, concerning the decompoſition of water, be exactly conformable to truth;—if, as I have endeavoured to prove, that ſubſtance be really compoſed of hydrogen, as its proper conſtituent element, combined with oxygen, it ought to follow, that, by reuniting theſe two elements together, we ſhould recompoſe water; and that this actually happens may be judged of by the following experiment.

Experiment Fourth.

I took a large criſtal baloon, A, Pl. iv. fig. 5. holding about 30 pints, having a large opening, to which was cemented the plate of copper BC, pierced with four holes, in which four tubes terminate. The firſt tube, H h, is intended to be be adapted to an air pump, by which the baloon is to be exhauſted of its air. The ſecond tube gg, communicates, by its extremity MM, with a reſervoir of oxygen gas, with which the baloon is to be filled. The third tube d D d', communicates, by its extremity d NN, with a reſervoir of hydrogen gas. The extremity d' of this tube terminates in a capillary opening, through which the hydrogen gas contained in the reſervoir is forced, with a moderate degree of quickneſs, by the preſſure of one or two inches of water. The fourth tube contains a metallic wire GL, having a knob at its extremity L, intended for giving an electrical ſpark from L to d', on purpoſe to ſet fire to the hydrogen gas: This wire is moveable in the tube, that we may be able to ſeparate the knob L from the extremity d' of the tube D d'. The three tubes d D d', gg, and H h, are all provided with ſtop-cocks.

That the hydrogen gas and oxygen gas may be as much as poſſible deprived of water, they are made to paſs, in their way to the baloon A, through the tubes MM, NN, of about an inch diameter, and filled with ſalts, which, from their deliqueſcent nature, greedily attract the moiſture of the air: Such are the acetite of potaſh, and the muriat or nitrat of lime *. Theſe ſalts muſt

---

* See the nature of theſe ſalts in the ſecond part of this book.—A.

muſt only be reduced to a coarſe powder, leſt they run into lumps, and prevent the gaſſes from geting through their interſtices.

We muſt be provided before hand with a ſufficient quantity of oxygen gas, carefully purified from all admixture of carbonic acid, by long contact with a ſolution of potaſh *.

We muſt likewiſe have a double quantity of hydrogen gas, carefully purified in the ſame manner by long contact with a ſolution of potaſh in water. The beſt way of obtaining this gas free from mixture is, by decompoſing water with very pure ſoft iron, as directed in Exp. 3. of this chapter.

Having adjuſted every thing properly, as above directed, the tube H h is adapted to an air-pump, and the baloon A is exhauſted of its air. We next admit the oxygen gas ſo as to fill the baloon, and then, by means of preſſure, as is before mentioned, force a ſmall ſtream of hydrogen gas through its tube D d', which we immediately ſet on fire by an electric ſpark. By means of the above deſcribed apparatus, we can continue

---

* By potaſh is here meant, pure or cauſtic alkali, deprived of carbonic acid by means of quick-lime: In general, we may obſerve here, that all the alkalies and earths muſt invariably be conſidered as in their pure or cauſtic ſtate, unleſs otherwiſe expreſſed.—E. The method of obtaining this pure alkali of potaſh will be given in the ſequel.—A.

continue the mutual combuſtion of theſe two gaſſes for a long time, as we have the power of ſupplying them to the baloon from their reſervoirs, in proportion as they are conſumed. I have in another place * given a deſcription of the apparatus uſed in this experiment, and have explained the manner of aſcertaining the quantities of the gaſſes conſumed with the moſt ſcrupulous exactitude.

In proportion to the advancement of the combuſtion, there is a depoſition of water upon the inner ſurface of the baloon or matraſs A: The water gradually increaſes in quantity, and, gathering into large drops, runs down to the bottom of the veſſel. It is eaſy to aſcertain the quantity of water collected, by weighing the baloon both before and after the experiment. Thus we have a twofold verification of our experiment, by aſcertaining both the quantities of the gaſſes employed, and of the water formed by their combuſtion: Theſe two quantities muſt be equal to each other. By an operation of this kind, Mr Meuſnier and I aſcertained that it required 85 parts, by weight, of oxygen, united to 15 parts of hydrogen, to compoſe 100 parts of water. This experiment, which has not hitherto been publiſhed, was made in preſence of a numerous committee from the Royal Academy.

---

* See the third part of this work.—A.

demy. We exerted the moſt ſcrupulous attention to its accuracy; and have reaſon to believe that the above propoſitions cannot vary a two hundredth part from abſolute truth.

From theſe experiments, both analytical and ſynthetic, we may now affirm that we have aſcertained, with as much certainty as is poſſible in phyſical or chemical ſubjects, that water is not a ſimple elementary ſubſtance, but is compoſed of two elements, oxygen and hydrogen; which elements, when exiſting ſeparately, have ſo ſtrong affinity for caloric, as only to ſubſiſt under the form of gas in the common temperature and preſſure of our atmoſphere.

This decompoſition and recompoſition of water is perpetually operating before our eyes, in the temperature of the atmoſphere, by means of compound elective attraction. We ſhall preſently ſee that the phenomena attendant upon vinous fermentation, putrefaction, and even vegetation, are produced, at leaſt in a certain degree, by decompoſition of water. It is very extraordinary that this fact ſhould have hitherto been overlooked by natural philoſophers and chemiſts: Indeed, it ſtrongly proves, that, in chemiſtry, as in moral philoſophy, it is extremely difficult to overcome prejudices imbibed in early education, and to ſearch for truth in any other road than the one we have been accuſtomed to follow.

I ſhall finiſh this chapter by an experiment much leſs demonſtrative than thoſe already related, but which has appeared to make more impreſſion than any other upon the minds of many people. When 16 ounces of alkohol are burnt in an apparatus * properly adapted for collecting all the water diſengaged during the combuſtion, we obtain from 17 to 18 ounces of water. As no ſubſtance can furniſh a product larger than its original bulk, it follows, that ſomething elſe has united with the alkohol during its combuſtion; and I have already ſhown that this muſt be oxygen, or the baſe of air. Thus alkohol contains hydrogen, which is one of the elements of water; and the atmoſpheric air contains oxygen, which is the other element neceſſary to the compoſition of water. This experiment is a new proof that water is a compound ſubſtance.

CHAP.

---

* See an account of this apparatus in the third part of this work.—A.

CHAP. IX.

Of the quantities of Caloric diſengaged from different ſpecies of Combuſtion.

WE have already mentioned, that, when any body is burnt in the center of a hollow ſphere of ice and ſupplied with air at the temperature of zero (32°), the quantity of ice melted from the inſide of the ſphere becomes a meaſure of the relative quantities of caloric diſengaged. Mr de la Place and I gave a deſcription of the apparatus employed for this kind of experiment in the Memoirs of the Academy for 1780, p. 355.; and a deſcription and plate of the ſame apparatus will be found in the third part of this work. With this apparatus, phoſphorus, charcoal, and hydrogen gas, gave the following reſults:

One pound of phoſphorus melted 100 *libs.* of ice.

One pound of charcoal melted 96 *libs.* 8 *oz.*

One pound of hydrogen gas melted 295 *libs.* 9 *oz.* 3½ *gros.*

As a concrete acid is formed by the combuſtion of phoſphorus, it is probable that very little caloric remains in the acid, and, conſequently,

quently, that the above experiment gives us very nearly the whole quantity of caloric contained in the oxygen gas. Even if we ſuppoſe the phoſphoric acid to contain a good deal of caloric, yet, as the phoſphorus muſt have contained nearly an equal quantity before combuſtion, the error muſt be very ſmall, as it will only conſiſt of the difference between what was contained in the phoſphorus before, and in the phoſphoric acid after combuſtion.

I have already ſhown in Chap. V. that one pound of phoſphorus abſorbs one pound eight ounces of oxygen during combuſtion; and ſince, by the ſame operation, 100 *lib.* of ice are melted, it follows, that the quantity of caloric contained in one pound of oxygen gas is capable of melting 66 *libs.* 10 *oz.* 5 *gros* 24 *grs.* of ice.

One pound of charcoal during combuſtion melts only 96 *libs.* 8 *oz.* of ice, whilſt it abſorbs 2 *libs.* 9 *oz.* 1 *gros* 10 *grs.* of oxygen. By the experiment with phoſphorus, this quantity of oxygen gas ought to diſengage a quantity of caloric ſufficient to melt 171 *libs.* 6 *oz.* 5 *gros.* of ice; conſequently, during this experiment, a quantity of caloric, ſufficient to melt 74 *libs.* 14 *oz.* 5 *gros* of ice diſappears. Carbonic acid is not, like phoſphoric acid, in a concrete ſtate after combuſtion but in the ſtate of gas, and requires to be united with caloric to enable it to ſubſiſt

ſubſiſt in that ſtate; the quantity of caloric miſſing in the laſt experiment is evidently employed for that purpoſe. When we divide that quantity by the weight of carbonic acid, formed by the combuſtion of one pound of charcoal, we find that the quantity of caloric neceſſary for changing one pound of carbonic acid from the concrete to the gaſſeous ſtate, would be capable of melting 20 *libs.* 15 *oz.* 5 *gros* of ice.

We may make a ſimilar calculation with the combuſtion of hydrogen gas and the conſequent formation of water. During the combuſtion of one pound of hydrogen gas, 5 *libs.* 10 *oz.* 5 *gros* 24 *grs.* of oxygen gas are abſorbed, and 295 *libs.* 9 *oz.* 3½ *gros.* of ice are melted. But 5 *libs.* 10 *oz.* 5 *gros* 24 *grs.* of oxygen gas, in changing from the aëriform to the ſolid ſtate, loſes, according to the experiment with phoſphorus, enough of caloric to have melted 377 *libs.* 12 *oz.* 3 *gros* of ice. There is only diſengaged, from the ſame quantity of oxygen, during its combuſtion with hydrogen gas, as much caloric as melts 295 *libs.* 2 *oz.* 3½ *gros*; wherefore there remains in the water at Zero (32°), formed, during this experiment, as much caloric as would melt 82 *libs.* 9 *oz.* 7½ *gros* of ice.

Hence, as 6 *libs.* 10 *oz.* 5 *gros* 24 *grs.* of water are formed from the combuſtion of one pound of hydrogen gas with 5 *libs.* 10 *oz.* 5 *gros* 24 *grs.* of oxygen, it follows that, in each

pound

pound of water, at the temperature of *Zero*, (32°), there exiſts as much caloric as would melt 12 *libs.* 5 *oz.* 2 *gros* 48 *grs.* of ice, without taking into account the quantity originally contained in the hydrogen gas, which we have been obliged to omit, for want of data to calculate its quantity. From this it appears that water, even in the ſtate of ice, contains a conſiderable quantity of caloric, and that oxygen, in entering into that combination, retains likewiſe a good proportion.

From theſe experiments, we may aſſume the following reſults as ſufficiently eſtabliſhed.

Combuſtion of Phoſphorus.

From the combuſtion of phoſphorus, as related in the foregoing experiments, it appears, that one pound of phoſphorus requires 1 *lib.* 8 *oz.* of oxygen gas for its combuſtion, and that 2 *libs.* 8 *oz.* of concrete phoſphoric acid are produced.

The quantity of caloric diſengaged by the combuſtion of one pound of phoſphorus, expreſſed by the number of pounds of ice melted during that operation, is . 100.00000.

The quantity diſengaged from each pound of oxygen, during the combuſtion of phoſphorus, expreſſed in the ſame manner, is 66.66667.

The quantity diſengaged during the formation

tion of one pound of phoſphoric acid, 40.00000
The quantity remaining in each pound of phoſphoric acid, 0.00600 *.

Combuſtion of Charcoal.

In the combuſtion of one pound of charcoal, 2 *libs.* 9 *oz.* 1 *gros* 10 *grs.* of oxygen gas are abſorbed, and 3 *libs.* 9 *oz.* 1 *gros* 10 *grs.* of carbonic acid gas are formed.

Caloric, diſengaged during the combuſtion of one pound of charcoal, 96.50000 †.

Caloric diſengaged during the combuſtion of charcoal, from each pound of oxygen gas abſorbed, 37.52823.

Caloric diſengaged during the formation of one pound of carbonic acid gas, 27.02024.

Caloric retained by each pound of oxygen after the combuſtion 29.13844

Caloric neceſſary for ſupporting one pound of carbonic acid in the ſtate of gas 20.97960.

Com-

---

[*] We here ſuppoſe the phoſphoric acid not to contain any caloric, which is not ſtrictly true; but, as I have before obſerved, the quantity it really contains is probably very ſmall, and we have not given it a value, for want of a ſufficient data to go upon.—A.

[†] All theſe relative quantities of caloric are expreſſed by the number of pounds of ice, and decimal parts, melted during the ſeveral operations.—E.

Combuſtion of Hydrogen Gas.

In the combuſtion of one pound of hydrogen gas; 5 *libs.* 10 *oz.* 5 *gros* 24 *grs.* of oxygen gas are abſorbed, and 6 *libs.* 10 *oz.* 5 *gros* 24 *grs.* of water are formed.

Caloric from each *lib.* of hydrogen gas,	295.58950.
Caloric from each *lib.* of oxygen gas,	52.16280.
Caloric diſengaged during the formation of each pound of water,	44.33840.
Caloric retained by each *lib.* of oxygen after combuſtion with hydrogen	14.50386.
Caloric retained by each *lib.* of water at the temperature of Zero (32°)	12.32823.

Of the Formation of Nitric Acid.

When we combine nitrous gas with oxygen gas, ſo as to form nitric or nitrous acid a degree of heat is produced, which is much leſs conſiderable than what is evolved during the other combinations of oxygen; whence it follows that oxygen, when it becomes fixed in nitric acid, retains a great part of the heat which it poſſeſſed

ſeſſed in the ſtate of gas. It is certainly poſſible to determine the quantity of caloric which is diſengaged during the combination of theſe two gaſſes, and conſequently to determine what quantity remains after the combination takes place. The firſt of theſe quantities might be aſcertained, by making the combination of the two gaſſes in an apparatus ſurrounded by ice; but, as the quantity of caloric diſengaged is very inconſiderable, it would be neceſſary to operate upon a large quantity of the two gaſſes in a very troubleſome and complicated apparatus. By this conſideration, Mr de la Place and I have hitherto been prevented from making the attempt. In the mean time, the place of ſuch an experiment may be ſupplied by calculations, the reſults of which cannot be very far from truth.

Mr de la Place and I deflagrated a convenient quantity of nitre and charcoal in an ice apparatus, and found that twelve pounds of ice were melted by the deflagration of one pound of nitre. We ſhall ſee, in the ſequel, that one pound of nitre is compoſed, as under, of

Potaſh	7 *oz.*	6 *gros*	51.84 *grs.*	= 4515.84 *grs.*
Dry acid	8	1	21.16	= 4700.16.

The above quantity of dry acid is compoſed of

Oxygen

Oxygen	6 *oz.*	3 *gros*	66.34 *grs.*	=	3738.34 *grs.*
Azote	1	5	25.82	=	961.82.

By this we ſind that, during the above deflagration, 2 *gros* $1\frac{1}{3}$ *gr.* of charcoal have ſuffered combuſtion, alongſt with 3738.34 *grs.* or 6 *oz.* 3 *gros* 66.34 *grs.* of oxygen. Hence, ſince 12 *libs.* of ice were melted during the combuſtion, it follows, that one pound of oxygen burnt in the ſame manner would have melted 29.58320 *libs.* of ice. To which the quantity of caloric, retained by a pound of oxygen after combining with charcoal to form carbonic acid gas, being added, which was already aſcertained to be capable of melting 29.13844 *libs.* of ice, we have for the total quantity of caloric remaining in a pound of oxygen, when combined with nitrous gas in the nitric acid 58.72164; which is the number of pounds of ice the caloric remaining in the oxygen in that ſtate is capable of melting.

We have before ſeen that, in the ſtate of oxygen gas, it contained at leaſt 66.66667; wherefore it follows that, in combining with azote to form nitric acid, it only loſes 7.94502. Farther experiments upon this ſubject are neceſſary to aſcertain how far the reſults of this calculation may agree with direct fact. This enormous quantity of caloric retained by oxygen in its combination into nitric acid, explains the cauſe

cauſe of the great diſengagement of caloric during the deflagrations of nitre; or, more ſtrictly ſpeaking, upon all occaſions of the decompoſition of nitric acid.

Of the Combuſtion of Wax.

Having examined ſeveral caſes of ſimple combuſtion, I mean now to give a few examples of a more complex nature. One pound of wax-taper being allowed to burn ſlowly in an ice apparatus, melted 133 *libs.* 2 *oz.* $5\frac{1}{3}$ *gros* of ice. According to my experiments in the Memoirs of the Academy for 1784, p. 606, one pound of wax-taper conſiſts of 13 *oz.* 1 *gros* 23 *grs.* of charcoal, and 2 *oz.* 6 *gros* 49 *grs.* of hydrogen.

By the foregoing experiments, the above quantity of charcoal ought to melt	79·39390 *libs.* of ice;
and the hydrogen ſhould melt	52·37605
In all	131.76995 *libs.*

Thus, we ſee the quantity of caloric diſengaged from a burning taper, is pretty exactly conformable to what was obtained by burning ſeparately a quantity of charcoal and hydrogen equal to what enters into its compoſition. Theſe experiments with the taper were ſeveral times repeated, ſo that I have reaſon to believe them accurate.

Combuſtion of Olive Oil.

We included a burning lamp, containing a determinate quantity of olive-oil, in the ordinary apparatus, and, when the experiment was finiſhed, we aſcertained exactly the quantities of oil conſumed, and of ice melted; the reſult was, that, during the combuſtion of one pound of olive-oil, 148 *libs.* 14 *oz.* 1 *gros* of ice were melted. By my experiments in the Memoirs of the Academy for 1784, and of which the following Chapter contains an abſtract, it appears that one pound of olive-oil conſiſts of 12 *oz.* 5 *gros* 5 *grs.* of charcoal, and 3 *oz.* 2 *gros* 67 *grs.* of hydrogen. By the foregoing experiments, that quantity of charcoal ſhould melt 76.18723 *libs.* of ice, and the quantity of hydrogen in a pound of the oil ſhould melt 62.15053 *libs.* The ſum of theſe two gives 138.33776 *libs.* of ice, which the two conſtituent elements of the oil would have melted, had they ſeparately ſuffered combuſtion, whereas the oil really melted 148.88330 *libs.* which gives an exceſs of 10.54554 in the reſult of the experiment

ment above the calculated reſult, from data furniſhed by former experiments.

This difference, which is by no means very conſiderable, may ariſe from errors which are unavoidable in experiments of this nature, or it may be owing to the compoſition of oil not being as yet exactly aſcertained. It proves, however, that there is a great agreement between the reſults of our experiments, reſpecting the combination of caloric, and thoſe which regard its diſengagement.

The following deſiderata ſtill remain to be determined, viz. What quantity of caloric is retained by oxygen, after combining with metals, ſo as to convert them into oxyds; What quantity is contained by hydrogen, in its different ſtates of exiſtence; and to aſcertain, with more preciſion than is hitherto attained, how much caloric is diſengaged during the formation of water, as there ſtill remain conſiderable doubts with reſpect to our preſent determination of this point, which can only be removed by farther experiments. We are at preſent occupied with this inquiry; and, when once theſe ſeveral points are well aſcertained, which we hope they will ſoon be, we ſhall probably be under the neceſſity of making conſiderable corrections upon moſt of the reſults of the experiments and calculations in this Chapter. I did not, however, conſider this as a ſufficient reaſon for withholding

holding ſo much as is already known from ſuch as may be inclined to labour upon the ſame ſubject. It is difficult, in our endeavours to diſcover the principles of a new ſcience, to avoid beginning by gueſs-work; and it is rarely poſſible to arrive at perfection from the firſt ſetting out.

CHAP. X.

Of the Combination of Combuſtible Subſtances with each other.

AS combuſtible ſubſtances in general have a great affinity for oxygen, they ought likewiſe to attract, or tend to combine with each other; *quae ſunt eadem uni tertio, ſunt eadem inter ſe;* and the axiom is found to be true. Almoſt all the metals, for inſtance, are capable of uniting with each other, and forming what are called *alloys**, in common language. Moſt of theſe, like all combinations, are ſuſceptible of ſeveral degrees of ſaturation; the greater number of theſe alloys are more brittle than the pure metals of which they are compoſed, eſpecially when the metals alloyed together are conſiderably different in their degrees of fuſibility. To this difference in fuſibility, part of the phenomena attendant upon *alloyage* are owing, particularly the property of iron, called by workmen

---

* This term *alloy*, which we have from the language of the arts, ſerves exceedingly well for diſtinguiſhing all the combinations or intimate unions of metals with each other, and is adopted in our new nomenclature for that purpoſe.—A.

men *hotſhort*. This kind of iron muſt be conſidered as an alloy, or mixture of pure iron, which is almoſt infuſible, with a ſmall portion of ſome other metal which fuſes in a much lower degree of heat. So long as this alloy remains cold, and both metals are in the ſolid ſtate, the mixture is malleable; but, if heated to a ſufficient degree to liquify the more fuſible metal, the particles of the liquid metal, which are interpoſed between the particles of the metal remaining ſolid, muſt deſtroy their continuity, and occaſion the alloy to become brittle. The alloys of mercury, with the other metals, have uſually been called *amalgams*, and we ſee no inconvenience from continuing the uſe of that term.

Sulphur, phoſphorus, and charcoal, readily unite with metals. Combinations of ſulphur with metals are uſually named *pyrites*. Their combinations with phoſphorus and charcoal are either not yet named, or have received new names only of late; ſo that we have not ſcrupled to change them according to our principles. The combinations of metal and ſulphur we call *ſulphurets*, thoſe with phoſphorus *phoſphurets*, and thoſe formed with charcoal *carburets*. Theſe denominations are extended to all the combinations into which the above three ſubſtances enter, without being previouſly oxygenated.

genated. Thus, the combination of ſulphur with potaſh, or fixed vegetable alkali, is called *ſulphuret of potaſh*; that which it forms with ammoniac, or volatile alkali, is termed *ſulphuret of ammoniac*.

Hydrogen is likewiſe capable of combining with many combuſtible ſubſtances. In the ſtate of gas, it diſſolves charcoal, ſulphur, phoſphorus, and ſeveral metals; we diſtinguiſh theſe combinations by the terms, *carbonated hydrogen gas*, *ſulphurated hydrogen gas*, and *phoſphorated hydrogen gas*. The ſulphurated hydrogen gas was called *hepatic air* by former chemiſts, or *foetid air from ſulphur*, by Mr Scheele. The virtues of ſeveral mineral waters, and the foetid ſmell of animal excrements, chiefly ariſe from the preſence of this gas. The phoſphorated hydrogen gas is remarkable for the property, diſcovered by Mr Gengembre, of taking fire ſpontaneouſly upon getting into contact with atmoſpheric air, or, what is better, with oxygen gas. This gas has a ſtrong flavour, reſembling that of putrid fiſh; and it is very probable that the phoſphoreſcent quality of fiſh, in the ſtate of putrefaction, ariſes from the eſcape of this ſpecies of gas. When hydrogen and charcoal are combined together, without the intervention of caloric, to bring the hydrogen into the ſtate of gas, they form oil, which is either fixed or volatile, according to the proportions of hydrogen and char-

charcoal in its compoſition. The chief difference between fixed or fat oils drawn from vegetables by expreſſion, and volatile or eſſential oils, is, that the former contains an exceſs of charcoal, which is ſeparated when the oils are heated above the degree of boiling water; whereas the volatile oils, containing a juſt proportion of theſe two conſtituent ingredients, are not liable to be decompoſed by that heat, but, uniting with caloric into the gaſſeous ſtate, paſs over in diſtillation unchanged.

In the Memoirs of the Academy for 1784, p. 593. I gave an account of my experiments upon the compoſition of oil and alkohol, by the union of hydrogen with charcoal, and of their combination with oxygen. By theſe experiments, it appears that fixed oils combine with oxygen during combuſtion, and are thereby converted into water and carbonic acid. By means of calculation applied to the products of theſe experiments, we find that fixed oil is compoſed of 21 parts, by weight, of hydrogen combined with 79 parts of charcoal. Perhaps the ſolid ſubſtances of an oily nature, ſuch as wax, contain a proportion of oxygen, to which they owe their ſtate of ſolidity. I am at preſent engaged in a ſeries of experiments, which I hope will throw great light upon this ſubject.

It is worthy of being examined, whether hydrogen in its concrete ſtate, uncombined with caloric,

caloric, be ſuſceptible of combination with ſulphur, phoſphorus, and the metals. There is nothing that we know of, which, *a priori*, ſhould render theſe combinations impoſſible; for combuſtible bodies being in general ſuſceptible of combination with each other, there is no evident reaſon for hydrogen being an exception to the rule: However, no direct experiment as yet eſtabliſhes either the poſſibility or impoſſibility of this union. Iron and zinc are the moſt likely, of all the metals, for entering into combination with hydrogen; but, as theſe have the property of decompoſing water, and as it is very difficult to get entirely free from moiſture in chemical experiments, it is hardly poſſible to determine whether the ſmall portions of hydrogen gas, obtained in certain experiments with theſe metals, were previouſly combined with the metal in the ſtate of ſolid hydrogen, or if they were produced by the decompoſition of a minute quantity of water. The more care we take to prevent the preſence of water in theſe experiments, the leſs is the quantity of hydrogen gas procured; and, when very accurate precautions are employed, even that quantity becomes hardly ſenſible.

However this inquiry may turn out reſpecting the power of combuſtible bodies, as ſulphur, phoſphorus, and metals, to abſorb hydrogen, we are certain that they only abſorb a very ſmall portion ; and that this combination, inſtead of being eſſential to their conſtitution, can only be conſidered as a foreign ſubſtance, which contaminates their purity. It is the province of the advocates * for this ſyſtem to prove, by deciſive experiments, the real exiſtence of this combined hydrogen, which they have hitherto only done by conjectures founded upon ſuppoſitions.

CHAP.

---

[*] By theſe are meant the ſupporters of the phlogiſtic theory, who at preſent conſider hydrogen, or the baſe of inflammable air, as the phlogiſton of the celebrated Stahl.—E.

CHAP. XI.

Obſervations upon Oxyds and Acids with ſeveral Baſes—and upon the Compoſition of Animal and Vegetable Subſtances.

WE have, in Chap. V. and VIII. examined the products reſulting from the combuſtion of the four ſimple combuſtible ſubſtances, ſulphur, phoſphorus, charcoal, and hydrogen: We have ſhown, in Chap. X. that the ſimple combuſtible ſubſtances are capable of combining with each other into compound combuſtible ſubſtances, and have obſerved that oils in general, and particularly the fixed vegetable oils, belong to this claſs, being compoſed of hydrogen and charcoal. It remains, in this chapter, to treat of the oxygenation of theſe compound combuſtible ſubſtances, and to ſhow that there exiſt acids and oxyds having double and triple baſes. Nature furniſhes us with numerous examples of this kind of combinations, by means of which, chiefly, ſhe is enabled to produce a vaſt variety of compounds from a very limited number of elements, or ſimple ſubſtances.

It was long ago well known, that, when muriatic and nitric acids were mixed together, a compound acid was formed, having properties quite diſtinct from thoſe of either of the acids taken ſeparately. This acid was called *aqua regia*, from its moſt celebrated property of diſſolving gold, called *king of metals* by the alchymiſts. Mr Berthollet has diſtinctly proved that the peculiar properties of this acid ariſe from the combined action of its two acidifiable baſes; and for this reaſon we have judged it neceſſary to diſtinguiſh it by an appropriate name: That of *nitro-muriatic* acid appears extremely applicable, from its expreſſing the nature of the two ſubſtances which enter into its compoſition.

This phenomenon of a double baſe in one acid, which had formerly been obſerved only in the nitro-muriatic acid, occurs continually in the vegetable kingdom, in which a ſimple acid, or one poſſeſſed of a ſingle acidifiable baſe, is very rarely found. Almoſt all the acids procurable from this kingdom have baſes compoſed of charcoal and hydrogen, or of charcoal, hydrogen, and phoſphorus, combined with more or leſs oxygen. All theſe baſes, whether double or triple, are likewiſe formed into oxyds, having leſs oxygen than is neceſſary to give them the properties of acids. The acids and oxyds from the animal kingdom are ſtill more compound, as their baſes generally conſiſt of a combination

bination of charcoal, phoſphorus, hydrogen, and azote.

As it is but of late that I have acquired any clear and diſtinct notions of theſe ſubſtances, I ſhall not, in this place, enlarge much upon the ſubject, which I mean to treat of very fully in ſome memoirs I am preparing to lay before the Academy. Moſt of my experiments are already performed; but, to be able to give exact reports of the reſulting quantities, it is neceſſary that they be carefully repeated, and increaſed in number: Wherefore, I ſhall only give a ſhort enumeration of the vegetable and animal acids and oxyds, and terminate this article by a few reflections upon the compoſition of vegetable and animal bodies.

Sugar, mucus, under which term we include the different kinds of gums, and ſtarch, are vegetable oxyds, having hydrogen and charcoal combined, in different proportions, as their radicals or baſes, and united with oxygen, ſo as to bring them to the ſtate of oxyds. From the ſtate of oxyds they are capable of being changed into acids by the addition of a freſh quantity of oxygen; and, according to the degrees of oxygenation, and the proportion of hydrogen and charcoal in their baſes, they form the ſeveral kinds of vegetable acids.

It would be eaſy to apply the principles of our nomenclature to give names to theſe vegetable acids and oxyds, by uſing the names of the two ſubſtances which compoſe their baſes: They would thus become hydro-carbonous acids and oxyds: In this method we might indicate which of their elements exiſted in exceſs, without circumlocution, after the manner uſed by Mr Rouelle for naming vegetable extracts: He calls theſe extracto-reſinous when the extractive matter prevails in their compoſition, and reſino-extractive when they contain a larger proportion of reſinous matter. Upon that plan, and by varying the terminations according to the formerly eſtabliſhed rules of our nomenclature, we have the following denominations: Hydro-carbonous, hydro-carbonic; carbono-hydrous, and carbono-hydric oxyds. And for the acids: Hydro-carbonous, hydro carbonic, oxygenated hydro-carbonic; carbono-hydrous, carbono-hydric, and oxygenated carbono-hydric. It is probable that the above terms would ſuffice for indicating all the varieties in nature, and that, in proportion as the vegetable acids become well underſtood, they will naturally arrange themſelves under theſe denominations. But, though we know the elements of which theſe are compoſed, we are as yet ignorant of the proportions of theſe ingredients, and are ſtill far from being able to claſs them in the above methodical manner; wherefore, we have determined to retain the ancient names proviſionally. I am ſomewhat farther advanced in this inquiry than at the time of publiſhing our conjunct eſſay upon chemical nomenclature; yet it would be improper to draw decided conſequences from experiments not yet ſufficiently preciſe: Though I acknowledge that this part of chemiſtry ſtill remains in ſome degree obſcure, I muſt expreſs my expectations of its being very ſoon elucidated.

I am ſtill more forcibly neceſſitated to follow the ſame plan in naming the acids, which have three or four elements combined in their baſes; of theſe we have a conſiderable number from the animal kingdom, and ſome even from vegetable ſubſtances. Azote, for inſtance, joined to hydrogen and charcoal, form the baſe or radical of the Pruſſic acid; we have reaſon to believe that the ſame happens with the baſe of the Gallic acid; and almoſt all the animal acids have their baſes compoſed of azote, phoſphorus, hydrogen, and charcoal. Were we to endeavour to expreſs at once all theſe four component parts of the baſes, our nomenclature would undoubtedly be methodical; it would have the property of being clear and determinate; but this aſſemblage of Greek and Latin ſubſtantives and adjectives, which are not yet univerſally admitted by chemiſts, would have the appearance of a barbarous language, difficult both to pronounce and to be remembered. Beſides, this part of chemiſtry being ſtill far from that accuracy it muſt arrive to, the perfection of the ſcience ought certainly to precede that of its language; and we muſt ſtill, for ſome time, retain the old names for the animal oxyds and acids. We have only ventured to make a few ſlight modifications of theſe names, by changing the termination into *ous*, when we have reaſon to ſuppoſe the baſe to be in exceſs, and into *ic*, when we ſuſpect the oxygen predominates.

The following are all the vegetable acids hitherto known:

1. Acetous acid.
2. Acetic acid.
3. Oxalic acid.
4. Tartarous acid.
5. Pyro-tartarous acid.
6. Citric acid.
7. Malic acid.
8. Pyro-mucous acid.
9. Pyro-lignous acid.
10. Gallic acid.
11. Benzoic acid.
12. Camphoric acid.
13. Succinic acid.

Though all theſe acids, as has been already ſaid, are chiefly, and almoſt entirely, compoſed of hydrogen, charcoal, and oxygen, yet, properly ſpeaking, they contain neither water carbonic acid nor oil, but only the elements neceſſary for forming theſe ſubſtances. The power of affinity reciprocally exerted by the hydrogen, charcoal, and oxygen, in theſe acids, is in a ſtate

of

of equilibrium only capable of exiſting in the ordinary temperature of the atmoſphere; for, when they are heated but a very little above the temperature of boiling water, this equilibrium is deſtroyed, part of the oxygen and hydrogen unite, and form water; part of the charcoal and hydrogen combine into oil; part of the charcoal and oxygen unite to form carbonic acid; and, laſtly, there generally remains a ſmall portion of charcoal, which, being in exceſs with reſpect to the other ingredients, is left free. I mean to explain this ſubject ſomewhat farther in the ſucceeding chapter.

The oxyds of the animal kingdom are hitherto leſs known than thoſe from the vegetable kingdom, and their number is as yet not at all determined. The red part of the blood, lymph, and moſt of the ſecretions, are true oxyds, under which point of view it is very important to conſider them. We are only acquainted with ſix animal acids, ſeveral of which, it is probable, approach very near each other in their nature, or, at leaſt, differ only in a ſcarcely ſenſible degree. I do not include the phoſphoric acid amongſt theſe, becauſe it is found in all the kingdoms of nature. They are,

1. Lactic acid.
2. Saccho-lactic acid.
3. Bombic acid.
4. Formic acid.
5. Sebacic acid.
6. Pruſſic acid.

The connection between the conſtituent elements of the animal oxyds and acids is not more permanent than in thoſe from the vegetable kingdom, as a ſmall increaſe of temperature is ſufficient to overturn it. I hope to render this ſubject more diſtinct than has been done hitherto in the following chapter.

CHAP. XII.

Of the Decompoſition of Vegetable and Animal Subſtances by the Action of Fire.

BEFORE we can thoroughly comprehend what takes place during the decompoſition of vegetable ſubſtances by fire, we muſt take into conſideration the nature of the elements which enter into their compoſition, and the different affinities which the particles of theſe elements exert upon each other, and the affinity which caloric poſſeſſes with them. The true conſtituent elements of vegetables are hydrogen, oxygen, and charcoal: Theſe are common to all vegetables, and no vegetable can exiſt without them: Such other ſubſtances as exiſt in particular vegetables are only eſſential to the compoſition of thoſe in which they are found, and do not belong to vegetables in general.

Of theſe elements, hydrogen and oxygen have a ſtrong tendency to unite with caloric, and be converted into gas, whilſt charcoal is a fixed element, having but little affinity with caloric. On the other hand, oxygen, which, in the uſual temperature, tends nearly equally to unite with hydrogen and with charcoal, has a much ſtronger er affinity with charcoal when at the red heat [*], and then unites with it to form carbonic acid.

Although we are far from being able to appreciate all theſe powers of affinity, or to expreſs their proportional energy by numbers, we are certain, that, however variable they may be when conſidered in relation to the quantity of caloric with which they are combined, they are all nearly in equilibrium in the uſual temperature of the atmoſphere; hence vegetables neither contain oil [†], water, nor carbonic acid, tho' they contain all the elements of theſe ſubſtances. The hydrogen is neither combined with the oxygen nor with the charcoal, and reciprocally; the particles of theſe three ſubſtances form a triple combination, which remains in equilibrium

---

[*] Though this term, red heat, does not indicate any abſolutely determinate degree of temperature, I ſhall uſe it ſometimes to expreſs a temperature conſiderably above that of boiling water.—A.

[†] I muſt be underſtood here to ſpeak of vegetables reduced to a perfectly dry ſtate; and, with reſpect to oil, I do not mean that which is procured by expreſſion either in the cold, or in a temperature not exceeding that of boiling water; I only allude to the empyreumatic oil procured by diſtillation with a naked fire, in a heat ſuperior to the temperature of boiling water; which is the only oil declared to be produced by the operation of fire. What I have publiſhed upon this ſubject in the Memoirs of the Academy for 1786 may be conſulted.—A.

brium whilſt undiſturbed by caloric but a very ſlight increaſe of temperature is ſufficient to overturn this ſtructure of combination.

If the increaſed temperature to which the vegetable is expoſed does not exceed the heat of boiling water, one part of the hydrogen combines with the oxygen, and forms water, the reſt of the hydrogen combines with a part of the charcoal, and forms volatile oil, whilſt the remainder of the charcoal, being ſet free from its combination with the other elements, remains fixed in the bottom of the diſtilling veſſel.

When, on the contrary, we employ a red heat, no water is formed, or, at leaſt, any that may have been produced by the firſt application of the heat is decompoſed, the oxygen having a greater affinity with the charcoal at this degree of heat, combines with it to form carbonic acid, and the hydrogen being left free from combination with the other elements, unites with caloric, and eſcapes in the ſtate of hydrogen gas. In this high temperature, either no oil is formed, or, if any was produced during the lower temperature at the beginning of the experiment, it is decompoſed by the action of the red heat. Thus the decompoſition of vegetable matter, under a high temperature, is produced by the action of double and triple affinities; while the charcoal attracts the oxygen,

on

on purpoſe to form carbonic acid, the caloric attracts the hydrogen, and converts it into hydrogen gas.

The diſtillation of every ſpecies of vegetable ſubſtance confirms the truth of this theory, if we can give that name to a ſimple relation of facts. When ſugar is ſubmitted to diſtillation, ſo long as we only employ a heat but a little below that of boiling water, it only loſes its water of criſtallization, it ſtill remains ſugar, and retains all its properties; but, immediately upon raiſing the heat only a little above that degree, it becomes blackened, a part of the charcoal ſeparates from the combination, water ſlightly acidulated paſſes over accompanied by a little oil, and the charcoal which remains in the retort is nearly a third part of the original weight of the ſugar.

The operation of affinities which take place during the decompoſition, by fire, of vegetables which contain azote, ſuch as the cruciferous plants, and of thoſe containing phoſphorus, is more complicated; but, as theſe ſubſtances only enter into the compoſition of vegetables in very ſmall quantities, they only, apparently, produce ſlight changes upon the products of diſtillation; the phoſphorus ſeems to combine with the charcoal, and, acquiring fixity from that union, remains behind in the retort, while the azote,

azote, combining with a part of the hydrogen, forms ammoniac, or volatile alkali.

Animal ſubſtances, being compoſed nearly of the ſame elements with cruciferous plants, give the ſame products in diſtillation, with this difference, that, as they contain a greater quantity of hydrogen and azote, they produce more oil and more ammoniac. I ſhall only produce one fact as a proof of the exactneſs with which this theory explains all the phenomena which occur during the diſtillation of animal ſubſtances, which is the rectification and total decompoſition of volatile animal oil, commonly known by the name of Dippel's oil. When theſe oils are procured by a firſt diſtillation in a naked fire they are brown, from containing a little charcoal almoſt in a free ſtate; but they become quite colourleſs by rectification. Even in this ſtate the charcoal in their compoſition has ſo ſlight a connection with the other elements as to ſeparate by mere expoſure to the air. If we put a quantity of this animal oil, well rectified, and conſequently clear, limpid, and tranſparent, into a bell-glaſs filled with oxygen gas over mercury, in a ſhort time the gas is much diminiſhed, being abſorbed by the oil, the oxygen combining with the hydrogen of the oil forms water, which ſinks to the bottom, at the ſame time the charcoal which was combined with the hydrogen being ſet free, manifeſts itſelf

by

by rendering the oil black. Hence the only way of preſerving theſe oils colourleſs and tranſparent, is by keeping them in bottles perfectly full and accurately corked, to hinder the contact of air, which always diſcolours them.

Succeſſive rectifications of this oil furniſh another phenomenon confirming our theory. In each diſtillation a ſmall quantity of charcoal remains in the retort, and a little water is formed by the union of the oxygen contained in the air of the diſtilling veſſels with the hydrogen of the oil. As this takes place in each ſucceſſive diſtillation, if we make uſe of large veſſels and a conſiderable degree of heat, we at laſt decompoſe the whole of the oil, and change it entirely into water and charcoal. When we uſe ſmall veſſels, and eſpecially when we employ a ſlow fire, or degree of heat little above that of boiling water, the total decompoſition of theſe oils, by repeated diſtillation, is greatly more tedious, and more difficultly accompliſhed. I ſhall give a particular detail to the Academy, in a ſeparate memoir, of all my experiments upon the decompoſition of oil; but what I have related above may ſuffice to give juſt ideas of the compoſition of animal and vegetable ſubſtances, and of their decompoſition by the action of fire.

CHAP. XIII.

Of the Decompoſition of Vegetable Oxyds by the Vinous Fermentation.

THE manner in which wine, cyder, mead, and all the liquors formed by the ſpiritous fermentation, are produced, is well known to every one. The juice of grapes or of apples being expreſſed, and the latter being diluted with water, they are put into large vats, which are kept in a temperature of at leaſt 10° (54.5°) of the thermometer. A rapid inteſtine motion, or fermentation, very ſoon takes place, numerous globules of gas form in the liquid and burſt at the ſurface; when the fermentation is at its height, the quantity of gas diſengaged is ſo great as to make the liquor appear as if boiling violently over a fire. When this gas is carefully gathered, it is found to be carbonic acid perfectly pure, and free from admixture with any other ſpecies of air or gas whatever.

When the fermentation is completed, the juice of grapes is changed from being ſweet, and full of ſugar, into a vinous liquor which no longer contains any ſugar, and from which we procure, by diſtillation, an inflammable liquor, known in commerce under the name of Spirit of Wine. As this liquor is produced by the fermentation of any ſaccharine matter whatever diluted with water, it muſt have been contrary to the principles of our nomenclature to call it ſpirit of wine rather than ſpirit of cyder, or of fermented ſugar; wherefore, we have adopted a more general term, and the Arabic word *alkohol* ſeems extremely proper for the purpoſe.

This operation is one of the moſt extraordinary in chemiſtry: We muſt examine whence proceed the diſengaged carbonic acid and the inflammable liquor produced, and in what manner a ſweet vegetable oxyd becomes thus converted into two ſuch oppoſite ſubſtances, whereof one is combuſtible, and the other eminently the contrary. To ſolve theſe two queſtions, it is neceſſary to be previouſly acquainted with the analyſis of the fermentable ſubſtance, and of the products of the fermentation. We may lay it down as an inconteſtible axiom, that, in all the operations of art and nature, nothing is created; an equal quantity of matter exiſts both before and after the experiment; the quality and quantity of the elements remain preciſely the ſame; and nothing takes place beyond changes and modifications in the combination of theſe elements. Upon this principle the whole art of performing chemical ex-

periments

periments depends: We muſt always ſuppoſe an exact equality between the elements of the body examined and thoſe of the products of its analyſis.

Hence, ſince from muſt of grapes we procure alkohol and carbonic acid, I have an undoubted right to ſuppoſe that muſt conſiſts of carbonic acid and alkohol. From theſe premiſes, we have two methods of aſcertaining what paſſes during vinous fermentation, by determining the nature of, and the elements which compoſe, the fermentable ſubſtances, or by accurately examining the products reſulting from fermentation; and it is evident that the knowledge of either of theſe muſt lead to accurate concluſions concerning the nature and compoſition of the other. From theſe conſiderations, it became neceſſary accurately to determine the conſtituent elements of the fermentable ſubſtances; and, for this purpoſe, I did not make uſe of the compound juices of fruits, the rigorous analyſis of which is perhaps impoſſible, but made choice of ſugar, which is eaſily analyſed, and the nature of which I have already explained. This ſubſtance is a true vegetable oxyd with two baſes, compoſed of hydrogen and charcoal brought to the ſtate of an oxyd, by a certain proportion of oxygen; and theſe three elements are combined in ſuch a way, that a very ſlight force is ſufficient to deſtroy the equilibrium of their connection. By a long train of experiments, made in various ways, and often repeated, I aſcertained that the proportion in which theſe ingredients exiſt in ſugar, are nearly eight parts of hydrogen, 64 parts of oxygen, and 28 parts of charcoal, all by weight, forming 100 parts of ſugar.

Sugar muſt be mixed with about four times its weight of water, to render it ſuſceptible of fermentation; and even then the equilibrium of its elements would remain undiſturbed, without the aſſiſtance of ſome ſubſtance, to give a commencement to the fermentation. This is accompliſhed by means of a little yeaſt from beer; and, when the fermentation is once excited, it continues of itſelf until completed. I ſhall, in another place, give an account of the effects of yeaſt, and other ferments, upon fermentable ſubſtances. I have uſually employed 10 *libs.* of yeaſt, in the ſtate of paſte, for each 100 *libs.* of ſugar, with as much water as is four times the weight of the ſugar. I ſhall give the reſults of my experiments exactly as they were obtained, preſerving even the fractions produced by calculation.

TABLE I. *Materials of Fermentation.*

		libs.	*oz.*	*gros*	*grs.*
Water		400	0	0	0
Sugar		100	0	0	0
Yeaſt in paſte, 10 *libs.* compoſed of	Water	7	3	6	44
	Dry yeaſt	2	12	1	28
	Total	510			

TABLE II. *Conſtituent Elements of the Materials of Fermentation.*

		libs.	*oz.*	*gros*	*grs.*
407 *libs*, 3 *oz.* 6 *gros* 44 *grs.* of water, compoſed of	Hydrogen	61	1	2	71.40
	Oxygen	346	2	3	44.60
100 *libs.* ſugar, compoſed of	Hydrogen	8	0	0	0
	Oxygen	64	0	0	0
	Charcoal	28	0	0	0
2 *libs.* 12 *oz.* 1 *gros* 28 *grs.* of dry yeaſt, compoſed of	Hydrogen	0	4	5	9.30
	Oxygen	1	10	2	28.76
	Charcoal	0	12	4	59
	Azote	0	0	5	2.94
	Total weight	510	0	0	0

TABLE

TABLE III. *Recapitulation of theſe Elements.*

		libs.	*oz.*	*gros*	*grs.*	*libs.*	*oz.*	*gros*	*grs.*
Oxygen	of the water	340	0	0	0	411	12	6	1.36
	of the water in the yeaſt	6	2	3	44.60				
	of the ſugar	64	0	0	0				
	of the dry yeaſt	1	10	2	28.76				
Hydrogen	of the water	60	0	0	0	69	6	0	8.70
	of the water in the yeaſt	1	1	2	71.40				
	of the ſugar	8	0	0	0				
	of the dry yeaſt	0	4	5	9.30				
Charcoal	of the ſugar	28	0	0	0	28	12	4	59.00
	of the yeaſt	0	12	4	59.00				
Azote of the yeaſt		-	-	-		0	0	5	2.94
					In all	510	0	0	0

Having thus accurately determined the nature and quantity of the conſtituent elements of the materials ſubmitted to fermentation, we have next to examine the products reſulting from that proceſs. For this purpoſe, I placed the above 510 *libs.* of fermentable liquor in a proper * apparatus, by means of which I could accurately determine the quantity and quality of gas diſengaged during the fermentation, and could even weigh every one of the products ſepa-

---

* The above apparatus is deſcribed in the Third Part.—A.

ſeparately, at any period of the proceſs I judged proper. An hour or two after the ſubſtances are mixed together, eſpecially if they are kept in a temperature of from 15° (65.75°) to 18° (72.5°) of the thermometer, the firſt marks of fermentation commence; the liquor turns thick and frothy, little globules of air are diſengaged, which riſe and burſt at the ſurface; the quantity of theſe globules quickly increaſes, and there is a rapid and abundant production of very pure carbonic acid, accompanied with a ſcum, which is the yeaſt ſeparating from the mixture. After ſome days, leſs or more according to the degree of heat, the inteſtine motion and diſengagement of gas diminiſh; but theſe do not ceaſe entirely, nor is the fermentation completed for a conſiderable time. During the proceſs, 35 *libs.* 5 *oz.* 4 *gros* 19 *grs.* of dry carbonic acid are diſengaged, which carry alongſt with them 13 *libs.* 14 *oz.* 5 *gros* of water. There remains in the veſſel 460 *libs.* 11 *oz.* 6 *gros* 53 *grs.* of vinous liquor, ſlightly acidulous. This is at firſt muddy, but clears of itſelf, and depoſits a portion of yeaſt. When we ſeparately analiſe all theſe ſubſtances, which is effected by very troubleſome proceſſes, we have the reſults as given in the following Tables. This proceſs, with all the ſubordinate calculations and analyſes, will be detailed at large in the Memoirs of the Academy.

TABLE IV. *Products of Fermentation.*

		libs.	*oz.*	*gros*	*grs.*
35 *libs.* 5 *oz.* 4 *gros* 19 *grs.* of carbonic acid, compoſed of	Oxygen - -	25	7	1	34
	Charcoal - -	9	14	2	57
408 *libs.* 15 *oz.* 5 *gros* 14 *grs.* of water, compoſed of	Oxygen -	347	10	0	59
	Hydrogen -	61	5	4	27
57 *libs.* 11 *oz.* 1 *gros* 58 *grs.* of dry alkohol, compoſed of	Oxygen, combined with hydrogen	31	6	1	64
	Hydrogen, combined with oxygen	5	8	5	3
	Hydrogen, combined with charcoal	4	0	5	0
	Charcoal, combined with hydrogen	16	11	5	63
2 *libs.* 8 *oz.* of dry acetous acid, compoſed of	Hydrogen -	0	2	4	0
	Oxygen - -	1	11	4	0
	Charcoal - -	0	10	0	0
4 *libs.* 1 *oz.* 4 *gros* 3 *grs.* of reſiduum of ſugar, compoſed of	Hydrogen - -	0	5	1	67
	Oxygen - -	2	9	7	27
	Charcoal - -	1	2	2	53
1 *lib.* 6 *oz.* 0 *gros* 5 *grs.* of dry yeaſt, compoſed of	Hydrogen -	0	2	2	41
	Oxygen - -	0	13	1	14
	Charcoal - -	0	6	2	30
	Azote - -	0	0	2	37
510 *libs.*	Total	510	0	0	0

TABLE

TABLE V. *Recapitulation of the Products.*

		libs,	*oz.*	*gros*	*grs.*
409 *libs.* 10 *oz.* 0 *gros* 54 *grs.* of oxygen contained in the	Water - -	347	10	0	59
	Carbonic acid -	25	7	1	34
	Alkohol - -	31	6	1	64
	Acetous acid -	1	11	4	0
	Reſiduum of ſugar	2	9	7	27
	Yeaſt - -	0	13	1	14
28 *libs.* 12 *oz.* 5 *gros* 59 *grs.* of charcoal contained in the	Carbonic acid -	9	14	2	57
	Alkohol -	16	11	5	63
	Acetous acid -	0	10	0	0
	Reſiduum of ſugar	1	2	2	53
	Yeaſt - -	0	6	2	30
71 *libs.* 8 *oz.* 6 *gros* 66 *grs.* of hydrogen, contained in the	Water - -	61	5	4	27
	Water of the alkohol	5	8	5	3
	Combined with the charcoal of the alko.	4	0	5	0
	Acetous acid -	0	2	4	0
	Reſiduum of ſugar	0	5	1	67
	Yeaſt - -	0	2	2	41
	2 *gros* 37 *grs.* of azote in the yeaſt	0	0	2	37
510 *libs.*	Total	510	0	0	0

In theſe reſults, I have been exact, even to grains; not that it is poſſible, in experiments of this nature, to carry our accuracy ſo far, but as the experiments were made only with a few pounds of ſugar, and as, for the ſake of compariſon, I reduced the reſults of the actual experiments to the quintal or imaginary hundred pounds, I thought it neceſſary to leave the fractional parts preciſely as produced by calculation.

When we conſider the reſults preſented by theſe tables with attention, it is eaſy to diſcover exactly what occurs during fermentation. In the firſt place, out of the 100 *libs.* of ſugar employed, 4 *libs.* 1 *oz.* 4 *gros* 3 *grs.* remain, without having ſuffered decompoſition; ſo that, in reality, we have only operated upon 95 *libs.* 14 *oz.* 3 *gros* 69 *grs.* of ſugar; that is to ſay, upon 61 *libs.* 6 *oz.* 45 *grs.* of oxygen, 7 *libs.* 10 *oz.* 6 *gros* 6 *grs.* of hydrogen, and 26 *libs.* 13 *oz.* 5 *gros* 19 *grs.* of charcoal. By comparing theſe quantities, we find that they are fully ſufficient for forming the whole of the alkohol, carbonic acid and acetous acid produced by the fermentation. It is not, therefore, neceſſary to ſuppoſe that any water has been decompoſed during the experiment, unleſs it be pretended that the oxygen and hydrogen exiſt in the ſugar in that ſtate. On the contrary, I have already made it evident that hydrogen, oxygen and charcoal, the three conſtituent elements of vegetables, remain in a ſtate of equilibrium or mutual union with each other which ſubſiſts ſo long as this union remains undiſturbed by increaſed temperature, or by ſome new compound attraction; and that then only

only theſe elements combine, two and two together, to form water and carbonic acid.

The effects of the vinous fermentation upon ſugar is thus reduced to the mere ſeparation of its elements into two portions; one part is oxygenated at the expence of the other, ſo as to form carbonic acid, whilſt the other part, being diſoxyginated in favour of the former, is converted into the combuſtible ſubſtance alkohol; therefore, if it were poſſible to reunite alkohol and carbonic acid together, we ought to form ſugar. It is evident that the charcoal and hydrogen in the alkohol do not exiſt in the ſtate of oil, they are combined with a portion of oxygen, which renders them miſcible with water; wherefore theſe three ſubſtances, oxygen, hydrogen, and charcoal, exiſt here likewiſe in a ſpecies of equilibrium or reciprocal combination; and in fact, when they are made to paſs through a red hot tube of glaſs or porcelain, this union or equilibrium is deſtroyed, the elements become combined, two and two, and water and carbonic acid are formed.

I had formally advanced, in my firſt Memoirs upon the formation of water, that it was decompoſed in a great number of chemical experiments, and particularly during the vinous fermentation. I then ſuppoſed that water exiſted ready formed in ſugar, though I am now convinced that ſugar only contains the elements proper for compoſing it. It may be readily conceived, that it muſt have coſt me a good deal to abandon my firſt notions, but by ſeveral years reflection, and after a great number of experiments and obſervations upon vegetable ſubſtances, I have fixed my ideas as above.

I ſhall finiſh what I have to ſay upon vinous fermentation, by obſerving, that it furniſhes us with the means of analyſing ſugar and every vegetable fermentable matter. We may conſider the ſubſtances ſubmitted to fermentation, and the products reſulting from that operation, as forming an algebraic equation ; and, by ſucceſſively ſuppoſing each of the elements in this equation unknown, we can calculate their values in ſucceſſion, and thus verify our experiments by calculation, and our calculation by experiment reciprocally. I have often ſucceſsfully employed this method for correcting the firſt reſults of my experiments, and to direct me in the proper road for repeating them to advantage. I have explained myſelf at large upon this ſubject, in a Memoir upon vinous fermentation already preſented to the Academy, and which will ſpeedily be publiſhed.

CHAP. XIV.

Of the Putrefactive Fermentation.

THE phenomena of putrefaction are cauſed, like thoſe of vinous fermentation, by the operation of very complicated affinities. The conſtituent elements of the bodies ſubmitted to this proceſs ceaſe to continue in equilibrium in the threefold combination, and form themſelves anew into binary combinations *, or compounds, conſiſting of two elements only; but theſe are entirely different from the reſults produced by the vinous fermentation. Inſtead of one part of the hydrogen remaining united with part of the water and charcoal to form alkohol, as in the vinous fermentation, the whole of the hydrogen is diſſipated, during putrefaction, in the form of hydrogen gas, whilſt, at the ſame time, the oxygen and charcoal, uniting with caloric, eſcape in the form of carbonic acid gas; ſo that, when the whole proceſs is finiſhed, eſpecially

---

* Binary combinations are ſuch as conſiſt of two ſimple elements combined together. Ternary, and quaternary, conſiſt of three and four elements.—E.

ally if the materials have been mixed with a ſufficient quantity of water, nothing remains but the earth of the vegetable mixed with a ſmall portion of charcoal and iron. Thus putrefaction is nothing more than a complete analyſis of vegetable ſubſtance, during which the whole of the conſtituent elements is diſengaged in form of gas, except the earth, which remains in the ſtate of mould *.

Such is the reſult of putrefaction when the ſubſtances ſubmitted to it contain only oxygen, hydrogen, charcoal and a little earth. But this caſe is rare, and theſe ſubſtances putrify imperfectly and with difficulty, and require a conſiderable time to complete their putrefaction. It is otherwiſe with ſubſtances containing azote, which indeed exiſts in all animal matters, and even in a conſiderable number of vegetable ſubſtances. This additional element is remarkably favourable to putrefaction; and for this reaſon animal matter is mixed with vegetable, when the putrefaction of theſe is wiſhed to be haſtened. The whole art of forming compoſts and dunghills, for the purpoſes of agriculture, conſiſts in the proper application of this admixture.

The addition of azote to the materials of putrefaction not only accelerates the proceſs, that

---

* In the Third Part will be given the deſcription of an apparatus proper for being uſed in experiments of this kind.—A.

that element likewiſe combines with part of the hydrogen, and forms a new ſubſtance called *volatile alkali* or *ammoniac.* The reſults obtained by analyſing animal matters, by different proceſſes, leave no room for doubt with regard to the conſtituent elements of ammoniac; whenever the azote has been previouſly ſeparated from theſe ſubſtances, no ammoniac is produced; and in all caſes they furniſh ammoniac only in proportion to the azote they contain. This compoſition of ammoniac is likewiſe fully proved by Mr Berthollet, in the Memoirs of the Academy for 1785, p. 316. where he gives a variety of analytical proceſſes by which ammoniac is decompoſed, and its two elements, azote and hydrogen, procured ſeparately.

I already mentioned in Chap. X. that almoſt all combuſtible bodies were capable of combining with each other; hydrogen gas poſſeſſes this quality in an eminent degree, it diſſolves charcoal, ſulphur, and phoſphorus, producing the compounds named *carbonated hydrogen gas*, *ſulphurated hydrogen gas*, and *phoſphorated hydrogen gas*. The two latter of theſe gaſſes have a peculiarly diſagreeable flavour; the ſulphurated hydrogen gas has a ſtrong reſemblance to the ſmell of rotten eggs, and the phoſphorated ſmells exactly like putrid fiſh. Ammoniac has likewiſe a peculiar odour, not leſs penetrating, or leſs diſagreeable, than theſe other gaſſes. From the

the mixture of theſe different flavours proceeds the fetor which accompanies the putrefaction of animal ſubſtances. Sometimes ammoniac predominates, which is eaſily perceived by its ſharpneſs upon the eyes; ſometimes, as in feculent matters, the ſulphurated gas is moſt prevalent; and ſometimes, as in putrid herrings, the phoſphorated hydrogen gas is moſt abundant.

I long ſuppoſed that nothing could derange or interrupt the courſe of putrefaction; but Mr Fourcroy and Mr Thouret have obſerved ſome peculiar phenomena in dead bodies, buried at a certain depth, and preſerved to a certain degree, from contact with air; having found the muſcular fleſh frequently converted into true animal fat. This muſt have ariſen from the diſengagement of the azote, naturally contained in the animal ſubſtance, by ſome unknown cauſe, leaving only the hydrogen and charcoal remaining, which are the elements proper for producing fat or oil. This obſervation upon the poſſibility of converting animal ſubſtances into fat may ſome time or other lead to diſcoveries of great importance to ſociety. The faeces of animals, and other excrementitious matters, are chiefly compoſed of charcoal and hydrogen, and approach conſiderably to the nature of oil, of which they furniſh a conſiderable quantity by diſtillation with a naked fire; but the intolerable foetor which accompanies all the products of of theſe ſubſtances prevents our expecting that, at leaſt for a long time, they can be rendered uſeful in any other way than as manures.

I have only given conjectural approximations in this Chapter upon the compoſition of animal ſubſtances, which is hitherto but imperfectly underſtood. We know that they are compoſed of hydrogen, charcoal, azote, phoſphorus, and ſulphur, all of which, in a ſtate of quintuple combination, are brought to the ſtate of oxyd by a larger or ſmaller quantity of oxygen. We are, however, ſtill unacquainted with the proportions in which theſe ſubſtances are combined, and muſt leave it to time to complete this part of chemical analyſis, as it has already done with ſeveral others.

CHAP. XV.

Of the Acetous Fermentation.

THE acetous fermentation is nothing more than the acidification or oxygenation of wine *, produced in the open air by means of the abſorption of oxygen. The reſulting acid is the acetous acid, commonly called Vinegar, which is compoſed of hydrogen and charcoal united together in proportions not yet aſcertained, and changed into the acid ſtate by oxygen. As vinegar is an acid, we might conclude from analogy that it contains oxygen, but this is put beyond doubt by direct experiments: In the firſt place, we cannot change wine into vinegar without the contact of air containing oxygen; ſecondly, this proceſs is accompanied by a diminution of the volume of the air in which it is carried on from the abſorption of its oxygen; and, thirdly, wine may be changed into vinegar by any other means of oxygenation.

---

* The word Wine, in this chapter, is uſed to ſignify the liquor produced by the vinous fermentation, whatever vegetable ſubſtance may have been uſed for obtaining it.—E.

Independent of the proofs which theſe facts furniſh of the acetous acid being produced by the oxygenation of wine, an experiment made by Mr Chaptal, Profeſſor of Chemiſtry at Montpellier, gives us a diſtinct view of what takes place in this proceſs. He impregnated water with about its own bulk of carbonic acid from fermenting beer, and placed this water in a cellar in veſſels communicating with the air, and in a ſhort time the whole was converted into acetous acid. The carbonic acid gas procured from beer vats in fermentation is not perfectly pure, but contains a ſmall quantity of alkohol in ſolution, wherefore water impregnated with it contains all the materials neceſſary for forming the acetous acid. The alkohol furniſhes hydrogen and one portion of charcoal, the carbonic acid furniſhes oxygen and the reſt of the charcoal, and the air of the atmoſphere furniſhes the reſt of the oxygen neceſſary for changing the mixture into acetous acid. From this obſervation it follows, that nothing but hydrogen is wanting to convert carbonic acid into acetous acid; or more generally, that, by means of hydrogen, and according to the degree of oxygenation, carbonic acid may be changed into all the vegetable acids; and, on the contrary, that, by depriving any of the vegetable acids of their hydrogen, they may be converted into carbonic acid.

Although the principal facts relating to the acetous acid are well known, yet numerical exactitude is ſtill wanting, till furniſhed by more exact experiments than any hitherto performed; wherefore I ſhall not enlarge any farther upon the ſubject. It is ſufficiently ſhown by what has been ſaid, that the conſtitution of all the vegetable acids and oxyds is exactly conformable to the formation of vinegar; but farther experiments are neceſſary to teach us the proportion of the conſtituent elements in all theſe acids and oxyds. We may eaſily perceive, however, that this part of chemiſtry, like all the reſt of its diviſions, makes rapid progreſs towards perfection, and that it is already rendered greatly more ſimple than was formerly believed.

CHAP. XVI.

Of the Formation of Neutral Salts, and of their different Baſes.

WE have juſt ſeen that all the oxyds and acids from the animal and vegetable kingdoms are formed by means of a ſmall number of ſimple elements, or at leaſt of ſuch as have not hitherto been ſuſceptible of decompoſition, by means of combination with oxygen; theſe are azote, ſulphur, phoſphorus, charcoal, hydrogen, and the muriatic radical *. We may juſtly admire the ſimplicity of the means employed by nature to multiply qualities and forms, whether by combining three or four acidifiable baſes in different proportions, or by altering the doſe of oxygen employed for oxydating or acidifying them. We ſhall find the means no leſs ſimple and diverſified, and as abundantly productive of forms and qualities, in the order of bodies we are now about to treat of.

---

* I have not ventured to omit this element, as here enumerated with the other principles of animal and vegetable ſubſtances, though it is not at all taken notice of in the preceding chapters as entering into the compoſition of theſe bodies.—E.

Acidiſiable ſubſtances, by combining with oxygen, and their conſequent converſion into acids, acquire great ſuſceptibility of farther combination; they become capable of uniting with earthy and metallic bodies, by which means neutral ſalts are formed. Acids may therefore be conſidered as true *ſalifying* principles, and the ſubſtances with which they unite to form neutral ſalts may be called *ſaliſiable* baſes: The nature of the union which theſe two principles form with each other is meant as the ſubject of the preſent chapter.

This view of the acids prevents me from conſidering them as ſalts, though they are poſſeſſed of many of the principal properties of ſaline bodies, as ſolubility in water, &c. I have already obſerved that they are the reſult of a firſt order of combination, being compoſed of two ſimple elements, or at leaſt of elements which act as if they were ſimple, and we may therefore rank them, to uſe the language of Stahl, in the order of *mixts*. The neutral ſalts, on the contrary, are of a ſecondary order of combination, being formed by the union of two *mixts* with each other, and may therefore be termed *compounds*. Hence I ſhall not arrange the alkalies * or earths in the claſs of ſalts, to which I allot

---

* Perhaps my thus rejecting the alkalies from the claſs of ſalts may be conſidered as a capital defect in the

allot only ſuch as are compoſed of an oxygenated ſubſtance united to a baſe.

I have already enlarged ſufficiently upon the formation of acids in the preceding chapter, and ſhall not add any thing farther upon that ſubject; but having as yet given no account of the ſalifiable baſes which are capable of uniting with them to form neutral ſalts, I mean, in this chapter, to give an account of the nature and origin of each of theſe baſes. Theſe are potaſh, ſoda, ammoniac, lime, magneſia, barytes, argill *, and all the metallic bodies.

§ 1. *Of Potaſh.*

We have already ſhown, that, when a vegetable ſubſtance is ſubmitted to the action of fire in diſtilling veſſels, its component elements, oxygen, hydrogen, and charcoal, which formed a threefold combination in a ſtate of equilibrium, unite, two and two, in obedience to affinities which act conformable to the degree of heat employed.

---

the method I have adopted, and I am ready to admit the charge; but this inconvenience is compenſated by ſo many advantages, that I could not think it of ſufficient conſequence to make me alter my plan.—A.

* Called Alumine by Mr Lavoiſier; but as Argill has been in a manner naturalized to the language for this ſubſtance by Mr Kirwan, I have ventured to uſe it in preference.—E.

employed. Thus, at the firſt application of the fire, whenever the heat produced exceeds the temperature of boiling water, part of the oxygen and hydrogen unite to form water; ſoon after the reſt of the hydrogen, and part of the charcoal, combine into oil; and, laſtly, when the fire is puſhed to the red heat, the oil and water, which had been formed in the early part of the proceſs, become again decompoſed, the oxygen and charcoal unite to form carbonic acid, a large quantity of hydrogen gas is ſet free, and nothing but charcoal remains in the retort.

A great part of theſe phenomena occur during the combuſtion of vegetables in the open air; but, in this caſe, the preſence of the air introduces three new ſubſtances, the oxygen and azote of the air and caloric, of which two at leaſt produce conſiderable changes in the reſults of the operation. In proportion as the hydrogen of the vegetable, or that which reſults from the decompoſition of the water, is forced out in the form of hydrogen gas by the progreſs of the fire, it is ſet on fire immediately upon getting in contact with the air, water is again formed, and the greater part of the caloric of the two gaſſes becoming free produces flame. When all the hydrogen gas is driven out, burnt, and again reduced to water, the remaining charcoal continues to burn, but without flame; it is formed

formed into carbonic acid, which carries off a portion of caloric ſufficient to give it the gaſſeous form; the reſt of the caloric, from the oxygen of the air, being ſet free, produces the heat and light obſerved during the combuſtion of charcoal. The whole vegetable is thus reduced into water and carbonic acid, and nothing remains but a ſmall portion of gray earthy matter called aſhes, being the only really fixed principles which enter into the conſtitution of vegetables.

The earth, or rather aſhes, which ſeldom exceeds a twentieth part of the weight of the vegetable, contains a ſubſtance of a particular nature, known under the name of fixed vegetable alkali, or potaſh. To obtain it, water is poured upon the aſhes, which diſſolves the potaſh, and leaves the aſhes which are inſoluble; by afterwards evaporating the water, we obtain the potaſh in a white concrete form: It is very fixed even in a very high degree of heat. I do not mean here to deſcribe the art of preparing potaſh, or the method of procuring it in a ſtate of purity, but have entered upon the above detail that I might not uſe any word not previouſly explained.

The potaſh obtained by this proceſs is always leſs or more ſaturated with carbonic acid, which is eaſily accounted for: As the potaſh does not form, or at leaſt is not ſet free, but in proportion as the charcoal of the vegetable is converted into carbonic acid by the addition of oxygen, either from the air or the water, it follows, that each particle of potaſh, at the inſtant of its formation, or at leaſt of its liberation, is in contact with a particle of carbonic acid, and, as there is a conſiderable affinity between theſe two ſubſtances, they naturally combine together. Although the carbonic acid has leſs affinity with potaſh than any other acid, yet it is difficult to ſeparate the laſt portions from it. The moſt uſual method of accompliſhing this is to diſſolve the potaſh in water; to this ſolution add two or three times its weight of quicklime, then filtrate the liquor and evaporate it in cloſe veſſels; the ſaline ſubſtance left by the evaporation is potaſh almoſt entirely deprived of carbonic acid. In this ſtate it is ſoluble in an equal weight of water, and even attracts the moiſture of the air with great avidity; by this property it furniſhes us with an excellent means of rendering air or gas dry by expoſing them to its action. In this ſtate it is ſoluble in alkohol, though not when combined with carbonic acid; and Mr Berthollet employs this property as a method of procuring potaſh in the ſtate of perfect purity.

All vegetables yield leſs or more of potaſh in conſequence of combuſtion, but it is furniſhed in various degrees of purity by different vegetables; uſually, indeed, from all of them it is mixed

mixed with different ſalts from which it is eaſily ſeparable. We can hardly entertain a doubt that the aſhes, or earth which is left by vegetables in combuſtion, pre-exiſted in them before they were burnt, forming what may be called the ſkeleton, or oſſeous part of the vegetable. But it is quite otherwiſe with potaſh; this ſubſtance has never yet been procured from vegetables but by means of proceſſes or intermedia capable of furniſhing oxygen and azote, ſuch as combuſtion, or by means of nitric acid; ſo that it is not yet demonſtrated that potaſh may not be a produce from theſe operations. I have begun a ſeries of experiments upon this object, and hope ſoon to be able to give an account of their reſults.

§ 2. *Of Soda.*

Soda, like potaſh, is an alkali procured by lixiviation from the aſhes of burnt plants, but only from thoſe which grow upon the ſea-ſide, and eſpecially from the herb *kali*, whence is derived the name *alkali*, given to this ſubſtance by the Arabians. It has ſome properties in common with potaſh, and others which are entirely different: In general, theſe two ſubſtances have peculiar characters in their ſaline combinations which are proper to each, and conſequently diſtinguiſh them from each other; thus ſoda, which,

which, as obtained from marine plants, is uſually entirely ſaturated with carbonic acid, does not attract the humidity of the atmoſphere like potaſh, but, on the contrary, deſiccates, its criſtals effloreſce, and are converted into a white powder having all the properties of ſoda, which it really is, having only loſt its water of criſtallization.

Hitherto we are not better acquainted with the conſtituent elements of ſoda than with thoſe of potaſh, being equally uncertain whether it previouſly exiſted ready formed in the vegetable or is a combination of elements effected by combuſtion. Analogy leads us to ſuſpect that azote is a conſtituent element of all the alkalies, as is the caſe with ammoniac; but we have only ſlight preſumptions, unconfirmed by any deciſive experiments, reſpecting the compoſition of potaſh and ſoda.

§ 3. *Of Ammoniac.*

We have, however, very accurate knowledge of the compoſition of ammoniac, or volatile alkali, as it is called by the old chemiſts. Mr Berthollet, in the Memoirs of the Academy for 1784, p. 316. has proved by analyſis, that 1000 parts of this ſubſtance conſiſt of about 807 parts of azote combined with 193 parts of hydrogen.

Ammoniac

Ammoniac is chiefly procurable from animal ſubſtances by diſtillation, during which proceſs the azote and hydrogen neceſſary to its formation unite in proper proportions; it is not, however, procured pure by this proceſs, being mixed with oil and water, and moſtly ſaturated with carbonic acid. To ſeparate theſe ſubſtances it is firſt combined with an acid, the muriatic for inſtance, and then diſengaged from that combination by the addition of lime or potaſh. When ammoniac is thus produced in its greateſt degree of purity it can only exiſt under the gaſſeous form, at leaſt in the uſual temperature of the atmoſphere, it has an exceſſively penetrating ſmell, is abſorbed in large quantities by water, eſpecially if cold and aſſiſted by compreſſion. Water thus ſaturated with ammoniac has uſually been termed volatile alkaline fluor; we ſhall call it either ſimply ammoniac, or liquid ammoniac, and ammoniacal gas when it exiſts in the aëriform ſtate.

§ 4. *Of Lime, Magneſia, Barytes, and Argill.*

The compoſition of theſe four earths is totally unknown, and, until by new diſcoveries their conſtituent elements are aſcertained, we are certainly authoriſed to conſider them as ſimple bodies. Art has no ſhare in the production of theſe earths, as they are all procured ready formed ed from nature; but, as they have all, eſpecially the three firſt, great tendency to combination, they are never found pure. Lime is uſually ſaturated with carbonic acid in the ſtate of chalk, calcarious ſpars, moſt of the marbles, &c.; ſometimes with ſulphuric acid, as in gypſum and plaſter ſtones; at other times with fluoric acid forming vitreous or fluor ſpars; and, laſtly, it is found in the waters of the ſea, and of ſaline ſprings, combined with muriatic acid. Of all the ſalifiable baſes it is the moſt univerſally ſpread through nature.

Magneſia is found in mineral waters, for the moſt part combined with ſulphuric acid; it is likewiſe abundant in ſea-water, united with muriatic acid; and it exiſts in a great number of ſtones of different kinds.

Barytes is much leſs common than the three preceding earths; it is found in the mineral kingdom, combined with ſulphuric acid, forming heavy ſpars, and ſometimes, though rarely, united to carbonic acid.

Argill, or the baſe of alum, having leſs tendency to combination than the other earths, is often found in the ſtate of argill, uncombined with any acid. It is chiefly procurable from clays, of which, properly ſpeaking, it is the baſe, or chief ingredient.

§ 5. *Of Metallic Bodies.*

The metals, except gold, and ſometimes ſilver, are rarely found in the mineral kingdom in their metallic ſtate, being uſually leſs or more ſaturated with oxygen, or combined with ſulphur, arſenic, ſulphuric acid, muriatic acid, carbonic acid, or phoſphoric acid. Metallurgy, or the docimaſtic art, teaches the means of ſeparating them from theſe foreign matters; and for this purpoſe we refer to ſuch chemical books as treat upon theſe operations.

We are probably only acquainted as yet with a part of the metallic ſubſtances exiſting in nature, as all thoſe which have a ſtronger affinity to oxygen, than charcoal poſſeſſes, are incapable of being reduced to the metallic ſtate, and, conſequently, being only preſented to our obſervation under the form of oxyds, are confounded with earths. It is extremely probable that barytes, which we have juſt now arranged with earths, is in this ſituation; for in many experiments it exhibits properties nearly approaching to thoſe of metallic bodies. It is even poſſible that all the ſubſtances we call earths may be only metallic oxyds, irreducible by any hitherto known proceſs.

Thoſe metallic bodies we are at preſent acquainted with, and which we can reduce to the metallic

metallic or reguline ſtate, are the following ſeventeen:

1. Arſenic.
2. Molybdena.
3. Tungſtein.
4. Manganeſe.
5. Nickel.
6. Cobalt.
7. Biſmuth.
8. Antimony.
9. Zinc.
10. Iron.
11. Tin.
12. Lead.
13. Copper.
14. Mercury.
15. Silver.
16. Platina.
17. Gold.

I only mean to conſider theſe as ſalifiable baſes, without entering at all upon the conſideration of their properties in the arts, and for the uſes of ſociety. In theſe points of view each metal would require a complete treatiſe, which would lead me far beyond the bounds I have preſcribed for this work.

CHAP. XVII.

Continuation of the Obſervations upon Salifiable Baſes, and the Formation of Neutral Salts.

IT is neceſſary to remark, that earths and alkalies unite with acids to form neutral ſalts without the intervention of any medium, whereas metallic ſubſtances are incapable of forming this combination without being previouſly leſs or more oxygenated; ſtrictly ſpeaking, therefore, metals are not ſoluble in acids, but only metallic oxyds. Hence, when we put a metal into an acid for ſolution, it is neceſſary, in the firſt place, that it become oxygenated, either by attracting oxygen from the acid or from the water; or, in other words, that a metal cannot be diſſolved in an acid unleſs the oxygen, either of the acid, or of the water mixed with it, has a ſtronger affinity to the metal than to the hydrogen or the acidifiable baſe; or, what amounts to the ſame thing, that no metallic ſolution can take place without a previous decompoſition of the water, or the acid in which it is made. The explanation of the principal phenomena of metallic ſolution depends entirely upon this ſimple obſervation, which was overlooked even by the illuſtrious Bergman.

The firſt and moſt ſtriking of theſe is the effervefcence, or, to ſpeak leſs equivocally, the diſengagement of gas which takes place during the ſolution; in the ſolutions made in nitric acid this effervefcence is produced by the diſengagement of nitrous gas; in ſolutions with ſulphuric acid it is either ſulphurous acid gas or hydrogen gas, according as the oxydation of the metal happens to be made at the expence of the ſulphuric acid or of the water. As both nitric acid and water are compoſed of elements which, when ſeparate, can only exiſt in the gaſſeous form, at leaſt in the common temperature of the atmoſphere, it is evident that, whenever either of theſe is deprived of its oxygen, the remaining element muſt inſtantly expand and aſſume the ſtate of gas; the effervefcence is occaſioned by this ſudden converſion from the liquid to the gaſſeous ſtate. The ſame decompoſition, and conſequent formation of gas, takes place when ſolutions of metals are made in ſulphuric acid: In general, eſpecially by the humid way, metals do not attract all the oxygen it contains; they therefore reduce it, not into ſulphur, but into ſulphurous acid, and as this acid can only exiſt as gas in the uſual temperature, it is diſengaged, and occaſions effervefcence.

The

The ſecond phenomenon is, that, when the metals have been previouſly oxydated, they all diſſolve in acids without effervеſcence: This is eaſily explained; becauſe, not having now any occaſion for combining with oxygen, they neither decompoſe the acid nor the water by which, in the former caſe, the effervеſcence is occaſioned.

A third phenomenon, which requires particular conſideration, is, that none of the metals produce effervеſcence by ſolution in oxygenated muriatic acid. During this proceſs the metal, in the firſt place, carries off the exceſs of oxygen from the oygenated muriatic acid, by which it becomes oxydated, and reduces the acid to the ſtate of ordinary muriatic acid. In this caſe there is no production of gas, not that the muriatic acid does not tend to exiſt in the gaſſeous ſtate in the common temperature, which it does equally with the acids formerly mentioned, but becauſe this acid, which otherwiſe would expand into gas, finds more water combined with the oxygenated muriatic acid than is neceſſary to retain it in the liquid form; hence it does not diſengage like the ſulphurous acid, but remains, and quietly diſſolves and combines with the metallic oxyd previouſly formed from its ſuperabundant oxygen.

The fourth phenomenon is, that metals are abſolutely inſoluble in ſuch acids as have their

baſes

baſes joined to oxygen by a ſtronger affinity than theſe metals are capable of exerting upon that acidifying principle. Hence ſilver, mercury, and lead, in their metallic ſtates, are inſoluble in muriatic acid, but, when previouſly oxydated, they become readily ſoluble without efferveſcence.

From theſe phenomena it appears that oxygen is the bond of union between metals and acids; and from this we are led to ſuppoſe that oxygen is contained in all ſubſtances which have a ſtrong affinity with acids: Hence it is very probable the four eminently ſalifiable earths contain oxygen, and their capability of uniting with acids is produced by the intermediation of that element. What I have formerly noticed relative to theſe earths is conſiderably ſtrengthened by the above conſiderations, viz. that they may very poſſibly be metallic oxyds, with which oxygen has a ſtronger affinity than with charcoal, and conſequently not reducible by any known means.

All the acids hitherto known are enumerated in the following table, the firſt column of which contains the names of the acids according to the new nomenclature, and in the ſecond column are placed the baſes or radicals of theſe acids, with obſervations.

Names of the Acids.	*Names of the Baſes, with Obſervations.*
1. Sulphurous	Sulphur.
2. Sulphuric	
3. Phoſphorous	Phoſphorus.
4. Phoſphoric	
5. Muriatic	Muriatic radical or baſe, hitherto unknown.
6. Oxygenated muriatic	
7. Nitrous	Azote.
8. Nitric	
9. Oxygenated nitric	
10. Carbonic	Charcoal
11. Acetous	The baſes or radicals of all theſe acids ſeem to be formed by a combination of charcoal and hydrogen; and the only difference ſeems to be owing to the different proportions in which theſe elements combine to form their baſes, and to the different doſes of oxygen in their acidification. A connected ſeries of accurate experiments is ſtill wanted upon this ſubject.
12. Acetic	
13. Oxalic	
14. Tartarous	
15. Pyro-tartarous	
16. Citric	
17. Malic	
18. Pyro-lignous	
19. Pyro-mucous	
20. Gallic	Our Knowledge of the baſes of theſe acids is hitherto imperfect; we only know that they contain hydrogen and charcoal as principal elements, and that the pruſſic acid contains azote.
21. Pruſſic	
22. Benzoic	
23. Succinic	
24. Camphoric	
25. Lactic	
26. Saccho-lactic	
27. Bombic	The baſe of theſe and all the acids procured from animal ſubſtances ſeems to conſiſt of charcoal, hydrogen, phoſphorus, and azote.
28. Formic	
29. Sebacic	
30. Boracic	The baſes of theſe two are hitherto entirely unknown.
31. Fluoric	
32. Antimonic	Antimony.
33. Argentic	Silver.
34. Arſeniac *	Arſenic.

---

* This term ſwerves a little from the rule in making the name of this acid terminate in *ac* inſtead of *ic*. The baſe and acid are diſtinguiſhed in French by *arſenic* and *arſenique*; but, having choſen the Engliſh termination *ic* to tranſlate the French *ique*, I was obliged to uſe this ſmall deviation.—E.

	Names of the Acids.	*Names of the Baſes.*
35	Biſmuthic	Biſmuth.
36.	Cobaltic	Cobalt.
37.	Cupric	Copper.
38.	Stannic	Tin.
39.	Ferric	Iron.
40.	Munganic	Manganeſe.
41.	Mercuric *	Mercury.
42.	Molybdic	Molybdena.
43.	Nickolic	Nickel,
44.	Auric	Gold.
45.	Platinic	Platina.
46.	Plumbic	Lead.
47.	Tungſtic	Tungſtein.
48.	Zincic	Zinc.

In this liſt, which contains 48 acids, I have enumerated 17 metallic acids hitherto very imperfectly known, but upon which Mr Berthollet is about to publiſh a very important work. It cannot be pretended that all the acids which exiſt in nature, or rather all the acidifiable baſes, are yet diſcovered; but, on the other hand, there are conſiderable grounds for ſuppoſing that a more accurate inveſtigation than has hitherto been attempted will diminiſh the number of the vegetable acids, by ſhowing that ſeveral of theſe, at preſent conſidered as diſtinct acids, are only modi-

---

* Mr Lavoiſier has hydrargirique; but mercurius being uſed for the baſe or metal, the name of the acid, as above, is equally regular, and leſs harſh.—E.

modifications of others. All that can be done in the preſent ſtate of our knowledge is, to give a view of chemiſtry as it really is, and to eſtabliſh fundamental principles, by which ſuch bodies as may be diſcovered in future may receive names, in conformity with one uniform ſyſtem.

The known ſalifiable baſes, or ſubſtances capable of being converted into neutral ſalts by union with acids, amount to 24; viz. 3 alkalies, 4 earths, and 17 metallic ſubſtances; ſo that, in the preſent ſtate of chemical knowledge, the whole poſſible number of neutral ſalts amounts to 1152 *. This number is upon the ſuppoſition that the metallic acids are capable of diſſolving other metals, which is a new branch of chemiſtry not hitherto inveſtigated, upon which depends all the metallic combinations named *vitreous*. There is reaſon to believe that many of theſe ſuppoſable ſaline combinations are not capable of being formed, which muſt greatly reduce the real number of neutral ſalts producible by nature and art. Even if we ſuppoſe the real number to amount only to five or ſix hundred ſpecies of poſſible neutral ſalts, it is evident that, were we to diſtinguiſh them, after the

---

* This number excludes all triple ſalts, or ſuch as contain more than one ſalifiable baſe, all the ſalts whoſe baſes are over or under ſaturated with acid, and thoſe formed by the nitro-muriatic acid.—E.

the manner of the ancients, either by the names of their firſt diſcoverers, or by terms derived from the ſubſtances from which they are procured, we ſhould at laſt have ſuch a confuſion of arbitrary deſignations, as no memory could poſſibly retain. This method might be tolerable in the early ages of chemiſtry, or even till within theſe twenty years, when only about thirty ſpecies of ſalts were known; but, in the preſent times, when the number is augmenting daily, when every new acid gives us 24 or 48 new ſalts, according as it is capable of one or two degrees of oxygenation, a new method is certainly neceſſary. The method we have adopted, drawn from the nomenclature of the acids, is perfectly analogical, and, following nature in the ſimplicity of her operations, gives a natural and eaſy nomenclature applicable to every poſſible neutral ſalt.

In giving names to the different acids, we expreſs the common property by the generical term *acid*, and diſtinguiſh each ſpecies by the name of its peculiar acidifiable baſe. Hence the acids formed by the oxygenation of ſulphur, phoſphorus, charcoal, &c. are called *ſulphuric acid*, *phoſphoric acid*, *carbonic acid*, &c. We thought it likewiſe proper to indicate the different degrees of ſaturation with oxygen, by different terminations of the ſame ſpecific names. Hence

Hence we diſtinguiſh between ſulphurous and ſulphuric, and between phoſphorous and phoſphoric acids, &c.

By applying theſe principles to the nomenclature of neutral ſalts, we give a common term to all the neutral ſalts ariſing from the combination of one acid, and diſtinguiſh the ſpecies by adding the name of the ſalifiable baſe. Thus, all the neutral ſalts having ſulphuric acid in their compoſition are named *ſulphats;* thoſe formed by the phoſphoric acid, *phoſphats*, &c. The ſpecies being diſtinguiſhed by the names of the ſalifiable baſes gives us *ſulphat of potaſh*, *ſulphat of ſoda*, *ſulphat of ammoniac*, *ſulphat of lime*, *ſulphat of iron*, &c. As we are acquainted with 24 ſalifiable baſes, alkaline, earthy, and metallic, we have conſequently 24 ſulphats, as many phoſphats, and ſo on through all the acids. Sulphur is, however, ſuſceptible of two degrees of oxygenation, the firſt of which produces ſulphurous, and the ſecond, ſulphuric acid; and, as the neutral ſalts produced by theſe two acids, have different properties, and are in fact different ſalts, it becomes neceſſary to diſtinguiſh theſe by peculiar terminations; we have therefore diſtinguiſhed the neutral ſalts formed by the acids in the firſt or leſſer degree of oxygenation, by changing the termination *at* into *ite*, as *ſulphites*, *phoſphites* *, &c. Thus, oxygenated

---

* As all the ſpecific names of the acids in the new nomen-

genated or acidified ſulphur, in its two degrees of oxygenation is capable of forming 48 neutral ſalts, 24 of which are ſulphites, and as many ſulphats; which is likewiſe the caſe with all the acids capable of two degrees of oxygenation *.

It were both tireſome and unneceſſary to follow theſe denominations through all the varieties of their poſſible application; it is enough to have given the method of naming the various ſalts, which, when once well underſtood, is eaſily applied to every poſſible combination. The name of the combuſtible and acidifiable body being once known, the names of the acid it is capable of forming, and of all the neutral combinatious

---

nomenclature are adjectives, they would have applied ſeverally to the various ſalifiable baſes, without the invention of other terms, with perfect diſtinctneſs. Thus, *ſulphurous potaſh*, and *ſulphuric potaſh*, are equally diſtinct as *ſulphite of potaſh*, and *ſulphat of potaſh*; and have the advantage of being more eaſily retained in the memory, becauſe more naturally ariſing from the acids themſelves, than the arbitrary terminations adopted by Mr Lavoiſier.—E.

* There is yet a third degree of oxygenation of acids, as the oxygenated muriatic and oxygenated nitric acids. The terms applicable to the neutral ſalts reſulting from the union of theſe acids with ſalifiable baſes is ſupplied by the Author in the Second Part of this Work. Theſe are formed by prefixing the word *oxygenated* to the name of the ſalt produced by the ſecond degree of oxygenation. Thus, *oxygenated* muriat of potaſh, *oxygenated* nitrat of ſoda, &c.—E.

binations the acid is ſuſceptible of entering into, are moſt readily remembered. Such as require a more complete illuſtration of the methods in which the new nomenclature is applied will, in the Second Part of this book, find Tables which contain a full enumeration of all the neutral ſalts, and, in general, all the poſſible chemical combinations, ſo far as is conſiſtent with the preſent ſtate of our knowledge. To theſe I ſhall ſubjoin ſhort explanations, containing the beſt and moſt ſimple means of procuring the different ſpecies of acids, and ſome account of the general properties of the neutral ſalts they produce.

I ſhall not deny, that, to render this work more complete, it would have been neceſſary to add particular obſervations upon each ſpecies of ſalt, its ſolubility in water and alkohol, the proportions of acid and of ſalifiable baſe in its compoſition, the quantity of its water of criſtallization, the different degrees of ſaturation it is ſuſceptible of, and, finally, the degree of force or affinity with which the acid adheres to the baſe. This immenſe work has been already begun by Meſſrs Bergman, Morveau, Kirwan, and other celebrated chemiſts, but is hitherto only in a moderate ſtate of advancement, even the principles upon which it is founded are not perhaps ſufficiently accurate.

Theſe numerous details would have ſwelled this elementary treatiſe to much too great a ſize; beſides that, to have gathered the neceſſary materials, and to have completed all the ſeries of experiments requiſite, muſt have retarded the publication of this book for many years. This is a vaſt field for employing the zeal and abilities of young chemiſts, whom I would adviſe to endeavour rather to do well than to do much, and to aſcertain, in the firſt place, the compoſition of the acids, before entering upon that of the neutral ſalts. Every edifice which is intended to reſiſt the ravages of time ſhould be built upon a ſure foundation; and, in the preſent ſtate of chemiſtry, to attempt diſcoveries by experiments, either not perfectly exact, or not ſufficiently rigorous, will ſerve only to interrupt its progreſs, inſtead of contributing to its advancement.

PART II.

Of the Combination of Acids with Salifiable Baſes, and of the Formation of Neutral Salts.

INTRODUCTION.

IF I had ſtrictly followed the plan I at firſt laid down for the conduct of this work, I would have confined myſelf, in the Tables and accompanying obſervations which compoſe this Second Part, to ſhort definitions of the ſeveral known acids, and abridged accounts of the proceſſes by which they are obtainable, with a mere nomenclature or enumeration of the neutral ſalts which reſult from the combination of theſe acids with the various ſalifiable baſes. But I afterwards found that the addition of ſimilar Tables of all the ſimple ſubſtances which enter into

into the compoſition of the acids and oxyds, together with the various poſſible combinations of theſe elements, would add greatly to the utility of this work, without being any great increaſe to its ſize. Theſe additions, which are all contained in the twelve firſt ſections of this Part, and the Tables annexed to theſe, form a kind of recapitulation of the firſt fifteen Chapters of the Firſt Part: The reſt of the Tables and Sections contain all the ſaline combinations.

It muſt be very apparent that, in this Part of the Work, I have borrowed greatly from what has been already publiſhed by Mr de Morveau in the Firſt Volume of the *Encyclopedie par ordre des Matières*. I could hardly have diſcovered a better ſource of information, eſpecially when the difficulty of conſulting books in foreign languages is conſidered. I make this general acknowledgment on purpoſe to ſave the trouble of references to Mr de Morveau's work in the courſe of the following part of mine.

TABLE OF SIMPLE SUBSTANCES.

Simple ſubſtances belonging to all the kingdoms of nature, which may be conſidered as the elements of bodies.

New Names.	*Correſpondent old Names.*
Light	Light.
Caloric	Heat. Principle or element of heat. Fire. Igneous fluid. Matter of fire and of heat.
Oxygen	Dephlogiſticated air. Empyreal air. Vital air, or Baſe of vital air.
Azote	Phlogiſticated air or gas. Mephitis, or its baſe.
Hydrogen	Inflammable air or gas, or the baſe of inflammable air.

Oxydable and Acidifiable ſimple Subſtances not Metallic.

New Names.	*Correſpondent old names.*
Sulphur Phoſphorus Charcoal	The ſame names.
Muriatic radical Fluoric radical Boracic radical	Still unknown.

Oxydable and Acidifiable ſimple Metallic Bodies.

New Names.		*Correſpondent Old Names.*
Antimony	Regulus of	Antimony.
Arſenic		Arſenic.
Biſmuth		Biſmuth.
Cobalt		Cobalt.
Copper		Copper.
Gold		Gold.
Iron		Iron.
Lead		Lead.
Mangancſe		Manganeſe.
Mercury		Mercury.
Molybdena		Molybdena.
Nickel		Nickel.
Platina		Platina.
Silver		Silver.
Tin		Tin.
Tungſtein		Tungſtein.
Zinc		Zinc.

Salifiable

Salifiable ſimple Earthy Subſtances.

New Names.	*Correſpondent old Names.*
Lime	Chalk, calcareous earth. Quicklime.
Magneſia	Magneſia, baſe of Epſom ſalt. Calcined or cauſtic magneſia.
Barytes	Barytes, or heavy earth.
Argill	Clay, earth of alum.
Silex	Siliceous or vitrifiable earth.

SECT. I.—*Obſervations upon the Table of Simple Subſtances.*

The principle object of chemical experiments is to decompoſe natural bodies, ſo as ſeparately to examine the different ſubſtances which enter into their compoſition. By conſulting chemical ſyſtems, it will be found that this ſcience of chemical analyſis has made rapid progreſs in our own times. Formerly oil and ſalt were conſidered as elements of bodies, whereas later obſervation and experiment have ſhown that all ſalts, inſtead of being ſimple, are compoſed of an acid united to a baſe. The bounds of analyſis have been greatly enlarged by modern diſcoveries *; the acids are ſhown to be compoſed of oxygen, as an acidifying principle common to all, united in each to a particular baſe. I have proved what Mr Haſſenfratz had before

---

* See Memoirs of the Academy for 1776, p. 671. and for 1778, p. 535.—A.

before advanced, that theſe radicals of the acids are not all ſimple elements, many of them being, like the oily principle, compoſed of hydrogen and charcoal. Even the baſes of neutral ſalts have been proved by Mr Berthollet to be compounds, as he has ſhown that ammoniac is compoſed of azote and hydrogen.

Thus, as chemiſtry advances towards perfection, by dividing and ſubdividing, it is impoſſible to ſay where it is to end; and theſe things we at preſent ſuppoſe ſimple may ſoon be found quite otherwiſe. All we dare venture to affirm of any ſubſtance is, that it muſt be conſidered as ſimple in the preſent ſtate of our knowledge, and ſo far as chemical analyſis has hitherto been able to ſhow. We may even preſume that the earths muſt ſoon ceaſe to be conſidered as ſimple bodies; they are the only bodies of the ſalifiable claſs which have no tendency to unite with oxygen; and I am much inclined to believe that this proceeds from their being already ſaturated with that element. If ſo, they will fall to be conſidered as compounds conſiſting of ſimple ſubſtances, perhaps metallic, oxydated to a certain degree. This is only hazarded as a conjecture; and I truſt the reader will take care not to confound what I have related as truths, fixed on the firm baſis of obſervation and experiment, with mere hypothetical conjectures.

The fixed alkalies, potaſh, and ſoda, are omitted in the foregoing Table, becauſe they are evidently compound ſubſtances, though we are ignorant as yet what are the elements they are compoſed of.

TABLE *of compound oxydable and acidifiable baſes.*

	Names of the radicals.	
Oxydable or acidifiable baſe, from the mineral kingdom.	Nitro-muriatic radical or baſe of the acid formerly called aqua regia.	
Oxydable or acidifiable hydro-carbonous or carbono-hydrous radicals from the vegetable kingdom.	Tartarous radical or baſe.	
	Malic.	Radicals
	Citric.	
	Pyro-lignous.	
	Pyro-mucous.	
	Pyro-tartarous.	
	Oxalic.	
	Acetous.	
	Succinic.	
	Benzoic.	
	Camphoric.	
	Gallic.	
Oxydable or acidifiable radicals from the animal kingdom, which moſtly contain azote, and frequently phoſphorus.	Lactic.	
	Saccholactic.	
	Formic.	
	Bombic.	
	Sebacic.	
	Lithic.	
	Pruſſic.	

SECT.

---

* *Note.*——The radicals from the vegetable kingdom are converted by a firſt degree of oxygenation into vegetable oxyds, ſuch as ſugar, ſtarch, and gum or mucus: Thoſe of the animal kingdom by the ſame means form animal oxyds, as lymph, &c.—A.

SECT. II.—*Obſervations upon the Table of Compound Radicals.*

The older chemiſts being unacquainted with the compoſition of acids, and not ſuſpecting them to be formed by a peculiar radical or baſe for each, united to an acidifying principle or element common to all, could not conſequently give any name to ſubſtances of which they had not the moſt diſtant idea. We had therefore to invent a new nomenclature for this ſubject, though we were at the ſame time ſenſible that this nomenclature muſt be ſuſceptible of great modification when the nature of the compound radicals ſhall be better underſtood *.

The compound oxydable and acidifiable radicals from the vegetable and animal kingdoms, enumerated in the foregoing table, are not hitherto reducible to ſyſtematic nomenclature, becauſe their exact analyſis is as yet unknown. We only know in general, by ſome experiments of my own, and ſome made by Mr Haſſenfratz, that moſt of the vegetable acids, ſuch as the tartarous, oxalic, citric, malic, acetous, pyrotartarous, and pyromucous, have radicals compoſed of hydrogen and charcoal, combined in ſuch

---

* See Part I. Chap. XI. upon this ſubject.—A.

ſuch a way as to form ſingle baſes, and that theſe acids only differ from each other by the proportions in which theſe two ſubſtances enter into the compoſition of their baſes, and by the degree of oxygenation which theſe baſes have received. We know farther, chiefly from the experiments of Mr Berthollet, that the radicals from the animal kingdom, and even ſome of thoſe from vegetables, are of a more compound nature, and, beſides hydrogen and charcoal, that they often contain azote, and ſometimes phoſphorus; but we are not hitherto poſſeſſed of ſufficiently accurate experiments for calculating the proportions of theſe ſeveral ſubſtances. We are therefore forced, in the manner of the older chemiſts, ſtill to name theſe acids after the ſubſtances from which they are procured. There can be little doubt that theſe names will be laid aſide when our knowledge of theſe ſubſtances becomes more accurate and extenſive; the terms *hydro-carbonous*, *hydro-carbonic*, *carbono-hydrous*, and *carbono-hydric* *, will then become ſubſtituted for thoſe we now employ, which will then only remain as teſtimonies of the imperfect ſtate in which this part of chemiſtry was tranſmitted to us by our predeceſſors.

---

* See Part I. Chap. XI. upon the application of theſe names according to the proportions of the two ingredients.—A.

It is evident that the oils, being compoſed of hydrogen and charcoal combined, are true carbono-hydrous or hydro-carbonous radicals; and, indeed, by adding oxygen, they are convertible into vegetable oxyds and acids, according to their degrees of oxygenation. We cannot, however, affirm that oils enter in their entire ſtate into the compoſition of vegetable oxyds and acids; it is poſſible that they previouſly loſe a part either of their hydrogen or charcoal, and that the remaining ingredients no longer exiſt in the proportions neceſſary to conſtitute oils. We ſtill require farther experiments to elucidate theſe points.

Properly ſpeaking, we are only acquainted with one compound radical from the mineral kingdom, the nitro-muriatic, which is formed by the combination of azote with the muriatic radical. The other compound mineral acids have been much leſs attended to, from their producing leſs ſtriking phenomena.

SECT. III.—*Obſervations upon the Combinations of Light and Caloric with different Subſtances.*

I have not conſtructed any table of the combinations of light and caloric with the various ſimple and compound ſubſtances, becauſe our conceptions of the nature of theſe combinations are not hitherto ſufficiently accurate. We know,

know, in general, that all bodies in nature are imbued, ſurrounded, and penetrated in every way with caloric, which fills up every interval left between their particles; that, in certain caſes, caloric becomes fixed in bodies, ſo as to conſtitute a part even of their ſolid ſubſtance, though it more frequently acts upon them with a repulſive force, from which, or from its accumulation in bodies to a greater or leſſer degree, the transformation of ſolids into fluids, and of fluids to aëriform elaſticity, is entirely owing. We have employed the generic name *gas* to indicate this aëriform ſtate of bodies produced by a ſufficient accumulation of caloric; ſo that, when we wiſh to expreſs the aëriform ſtate of muriatic acid, carbonic acid, hydrogen, water, alkohol, &c. we do it by adding the word *gas* to their names; thus muriatic acid gas, carbonic acid gas, hydrogen gas, aqueous gas, alkoholic gas, &c.

The combinations of light, and its mode of acting upon different bodies, is ſtill leſs known. By the experiments of Mr Berthollet, it appears to have great affinity with oxygen, is ſuſceptible of combining with it, and contributes alongſt with caloric to change it into the ſtate of gas. Experiments upon vegetation give reaſon to believe that light combines with certain parts of vegetables, and that the green of their leaves, and the various colours of their flowers, is chiefly ly owing to this combination. This much is certain, that plants which grow in darkneſs are perfectly white, languid, and unhealthy, and that to make them recover vigour, and to acquire their natural colours, the direct influence of light is abſolutely neceſſary. Somewhat ſimilar takes place even upon animals: Mankind degenerate to a certain degree when employed in ſedentary manufactures, or from living in crowded houſes, or in the narrow lanes of large cities; whereas they improve in their nature and conſtitution in moſt of the country labours which are carried on in the open air. Organization, ſenſation, ſpontaneous motion, and all the operations of life, only exiſt at the ſurface of the earth, and in places expoſed to the influence of light. Without it nature itſelf would be lifeleſs and inanimate. By means of light, the benevolence of the Deity hath filled the ſurface of the earth with organization, ſenſation, and intelligence. The fable of Promotheus might perhaps be conſidered as giving a hint of this philoſophical truth, which had even preſented itſelf to the knowledge of the ancients. I have intentionally avoided any diſquiſitions relative to organized bodies in this work, for which reaſon the phenomena of reſpiration, ſanguification, and animal heat, are not conſidered; but I hope, at ſome future time, to be able to elucidate theſe curious ſubjects.

To face Page 185.

TABLE of the binary Combinations of Oxygen with ſimple Subſtances.

	Names of the ſimple ſubſtances.	First degree of oxygenation.		Second degree of oxygenation.		Third degree of oxygenation.		Fourth degree of oxygenation	
		New Names.	Ancient Names.	New Names.	Ancient Names.	New Names.	Ancient Names.	New Names.	Ancient Nam
Combinations of oxygen with ſimple non-metallic ſubſtances.	Caloric	Oxygen gas	Vital or dephlogiſticated air						
	Hydrogen	Water[*].							
	Azote	Nitrous oxyd, or baſe of nitrous gas	Nitrous gas or air	Nitrous acid	Smoaking nitrous acid	Nitric acid	Pale, or not ſmoaking nitrous acid	Oxygenated nitric acid	Unknown
	Charcoal	Oxyd of charcoal, or carbonic oxyd	Unknown	Carbonous acid	Unknown	Carbonic acid	Fixed air	Oxygenated carbonic acid	Unknown
	Sulphur	Oxyd of ſulphur	Soft ſulphur	Sulphurous acid	Sulphureous acid	Sulphuric acid	Vitriolic acid	Oxygenated ſulphuric acid	Unknown
	Phoſphorus	Oxyd of phoſphorus	Reſiduum from the combuſtion of phoſphorus	Phoſphorous acid	Volatile acid of phoſphorus	Phoſphoric acid	Phoſphoric acid	Oxygenated phoſphoric acid	Unknown
	Muriatic radical	Muriatic oxyd	Unknown	Muriatous acid	Unknown	Muriatic acid	Marine acid	Oxygenated muriatic acid	Dephlogiſticat marine aci
	Fluoric radical	Fluoric oxyd	Unknown	Fluorous acid	Unknown	Fluoric acid	Unknown till lately		
	Boracic radical	Boracic oxyd	Unknown	Boracous acid	Unknown	Boracic acid	Homberg's ſedative ſalt		
Combinations of oxygen with the ſimple metallic ſubſtances.	Antimony	Grey oxyd of antimony	Grey calx of antimony	White oxyd of antimony	White calx of antimony, diaphoretic antimony	Antimonic acid			
	Silver	Oxyd of ſilver	Calx of ſilver	. . . .	. . . .	Argentic acid			
	Arſenic	Grey oxyd of arſenic	Grey calx of arſenic	White oxyd of arſenic	White calx of arſenic	Arſeniac acid	Acid of arſenic	Oxygenated arſeniac acid	Unknown
	Biſmuth	Grey oxyd of biſmuth	Grey calx of biſmuth	White oxyd of biſmuth	White calx of biſmuth	Biſmuthic acid			
	Cobalt	Grey oxyd of cobalt	Grey calx of cobalt	. . . .	. . . .	Cobaltic acid			
	Copper	Brown oxyd of copper	Brown calx of copper	Blue and green oxyds of copper	Blue and green calces of copper	Cupric acid			
	Tin	Grey oxyd of tin	Grey calx of tin	White oxyd of tin	White calx of tin, or putty of tin	Stannic acid			
	Iron	Black oxyd of iron	Martial ethiops	Yellow and red oxyds of iron	Ochre and ruſt of iron	Ferric acid			
	Manganeſe	Black oxyd of manganeſe	Black calx of manganeſe	White oxyd of manganeſe	White calx of manganeſe	Manganeſic acid			
	Mercury	Black oxyd of mercury	Ethiops mineral [†]	Yellow and red oxyds of mercury	Turbith mineral, red precipitate, calcined mercury, precipitate *per ſe*	Mercuric acid			
	Molybdena	Oxyd of molybdena	Calx of molybdena	. . . .	. . . .	Molybdic acid	Acid of molybdena	Oxygenated molybdic acid	Unknown
	Nickel	Oxyd of nickel	Calx of nickel	. . . .	. . . .	Nickelic acid			
	Gold	Yellow oxyd of gold	Yellow calx of gold	Red oxyd of gold	Red calx of gold, purple precipitate of caſſius	Auric acid			
	Platina	Yellow oxyd of platina	Yellow calx of platina	. . . .	. . . .	Platinic acid			
	Lead	Grey oxyd of lead	Grey calx of lead	Yellow and red oxyds of lead	Maſſicot and minium	Plumbic acid			
	Tungſtein	Oxyd of Tungſtein	Calx of Tungſtein	. . . .	. . . .	Tungſtic acid	Acid of Tungſtein	Oxygenated Tungſtic acid	Unknown
	Zinc	Grey oxyd of zinc	Grey calx of zinc	White oxyd of zinc	White calx of zinc, pompholix	Zincic acid			

[*] Only one degree of oxygenation of hydrogen is hitherto known.—A.

[†] Ethiops mineral is the ſulphuret of mercury; this ſhould have been called black precipitate of mercury.—E.

SECT. IV.—*Obſervations upon the Combinations of Oxygen with the ſimple Subſtances.*

Oxygen forms almoſt a third of the maſs of our atmoſphere, and is conſequently one of the moſt plentiful ſubſtances in nature. All the animals and vegetables live and grow in this immenſe magazine of oxygen gas, and from it we procure the greateſt part of what we employ in experiments. So great is the reciprocal affinity between this element and other ſubſtances, that we cannot procure it diſengaged from all combination. In the atmoſphere it is united with caloric, in the ſtate of oxygen gas, and this again is mixed with about two thirds of its weight of azotic gas.

Several conditions are requiſite to enable a body to become oxygenated, or to permit oxygen to enter into combination with it. In the firſt place, it is neceſſary that the particles of the body to be oxygenated ſhall have leſs reciprocal attraction with each other than they have for the oxygen, which otherwiſe cannot poſſibly combine with them. Nature, in this caſe, may be aſſiſted by art, as we have it in our power to diminiſh the attraction of the particles of bodies almoſt at will by heating them, or, in other words, by introducing caloric into the interſtices between their particles; and, as the attraction of theſe particles for each other is diminiſhed in the inverſe ratio of their diſtance, it is evident that there muſt be a certain point of diſtance of particles when the affinity they poſſeſs with each other becomes leſs than that they have for oxygen, and at which oxygenation muſt neceſſarily take place if oxygen be preſent.

We can readily conceive that the degree of heat at which this phenomenon begins muſt be different in different bodies. Hence, on purpoſe to oxygenate moſt bodies, eſpecially the greater part of the ſimple ſubſtances, it is only neceſſary to expoſe them to the influence of the air of the atmoſphere in a convenient degree of temperature. With reſpect to lead, mercury, and tin, this needs be but little higher than the medium temperature of the earth; but it requires a more conſiderable degree of heat to oxygenate iron, copper, &c. by the dry way, or when this operation is not aſſiſted by moiſture. Sometimes oxygenation takes place with great rapidity, and is accompanied by great ſenſible heat, light, and flame; ſuch is the combuſtion of phoſphorus in atmoſpheric air, and of iron in oxygen gas. That of ſulphur is leſs rapid; and the oxygenation of lead, tin, and moſt of the metals, takes place vaſtly ſlower, and conſequently the diſengagement of caloric, and more eſpecially of light, is hardly ſenſible.

Some ſubſtances have ſo ſtrong an affinity with oxygen, and combine with it in ſuch low degrees of temperature, that we cannot procure them in their unoxygenated ſtate; ſuch is the muriatic acid, which has not hitherto been decompoſed by art, perhaps even not by nature, and which conſequently has only been found in the ſtate of acid. It is probable that many other ſubſtances of the mineral kingdom are neceſſarily oxygenated in the common temperature of the atmoſphere, and that being already ſaturated with oxygen, prevents their farther action upon that element.

There are other means of oxygenating ſimple ſubſtances beſides expoſure to air in a certain degree of temperature, ſuch as by placing them in contact with metals combined with oxygen, and which have little affinity with that element. The red oxyd of mercury is one of the beſt ſubſtances for this purpoſe, eſpecially with bodies which do not combine with that metal. In this oxyd the oxygen is united with very little force to the metal, and can be driven out by a degree of heat only ſufficient to make glaſs red hot; wherefore ſuch bodies as are capable of uniting with oxygen are readily oxygenated, by means of being mixed with red oxyd of mercury, and moderately heated. The ſame effect may be, to a certain degree, produced by means of the black oxyd of manganeſe, the red oxyd of lead, the oxyds of ſilver, and by moſt of the metallic oxyds, if we only take care to chooſe ſuch as have leſs affinity with oxygen than the bodies they are meant to oxygenate. All the metallic reductions and revivifications belong to this claſs of operations, being nothing more than oxygenations of charcoal, by means of the ſeveral metallic oxyds. The charcoal combines with the oxygen and with caloric, and eſcapes in form of carbonic acid gas, while the metal remains pure and revivified, or deprived of the oxygen which before combined with it in the form of oxyd.

All combuſtible ſubſtances may likewiſe be oxygenated by means of mixing them with nitrat of potaſh or of ſoda, or with oxygenated muriat of pot-aſh, and ſubjecting the mixture to a certain degree of heat; the oxygen, in this caſe, quits the nitrat or the muriat, and combines with the combuſtible body. This ſpecies of oxygenation requires to be performed with extreme caution, and only with very ſmall quantities; becauſe, as the oxygen enters into the compoſition of nitrats, and more eſpecially of oxygenated muriats, combined with almoſt as much caloric as is neceſſary for converting it into oxygen gas, this immenſe quantity of caloric becomes ſuddenly free the inſtant of the combination of the oxygen with the combuſtible body,

body, and produces ſuch violent exploſions as are perfectly irreſiſtible.

By the humid way we can oxygenate moſt combuſtible bodies, and convert moſt of the oxyds of the three kingdoms of nature into acids. For this purpoſe we chiefly employ the nitric acid, which has a very ſlight hold of oxygen, and quits it readily to a great number of bodies by the aſſiſtance of a gentle heat. The oxygenated muriatic acid may be uſed for ſeveral operations of this kind, but not in them all.

I give the name of *binary* to the combinations of oxygen with the ſimple ſubſtances, becauſe in theſe only two elements are combined. When three ſubſtances are united in one combination I call it *ternary*, and *quaternary* when the combination conſiſts of four ſubſtances united.

TABLE *of the combinations of Oxygen with the compound radicals.*

Names of the radicals.	*Names of the reſulting acids.*	
	New nomenclature.	*Old nomenclature.*
Nitro muriatic radical	Nitro muriatic acid	Aqua regia.
*		
Tartaric	Tartarous acid	Unknown till lately.
Malic	Malic acid	Ditto.
Citric	Citric acid	Acid of lemons.
Pyro-lignous	Pyro-lignous acid	Empyreumatic acid of wood.
Pyro-mucous	Pyro-mucous acid	Empyr. acid of ſugar.
Pyro-tartarous	Pyro-tartarous acid	Empyr. acid of tartar.
Oxalic	Oxalic acid	Acid of ſorel.
Acetic	Acetous acid	Vinegar, or acid of vinegar.
	Acetic acid	Radical vinegar.
Succinic	Succinic acid	Volatile ſalt of amber.
Benzoic	Benzoic acid	Flowers of benzoin.
Camphoric	Camphoric acid	Unknown till lately.
Gallic	Gallic acid	The aſtringent principle of vegetables.
**		
Lactic	Lactic acid	Acid of ſour whey.
Saccholactic	Saccholactic acid	Unknown till lately.
Formic	Formic acid	Acid of ants.
Bombic	Bombic acid	Unknown till lately.
Sebacic	Sebacic acid	Ditto.
Lithic	Lithic acid	Urinary calculus.
Pruſſic	Pruſſic acid	Colouring matter of Pruſſian blue.

SECT.

---

* Theſe radicals by a firſt degree of oxygenation form vegetable oxyds, as ſugar, ſtarch, mucus, &c.—A.

** Theſe radicals by a firſt degree of oxygenation form the animal oxyds, as lymph, red part of the blood, animal ſecretions, &c.—A.

SECT. V.—*Obſervations upon the Combinations of Oxygen with the Compound Radicals.*

I publiſhed a new theory of the nature and formation of acids in the Memoirs of the Academy for 1776, p. 671. and 1778, p. 535. in which I concluded, that the number of acids muſt be greatly larger than was till then ſuppoſed. Since that time, a new field of inquiry has been opened to chemiſts; and, inſtead of five or ſix acids which were then known, near thirty new acids have been diſcovered, by which means the number of known neutral ſalts have been increaſed in the ſame proportion. The nature of the acidifiable baſes, or radicals of the acids, and the degrees of oxygenation they are ſuſceptible of, ſtill remain to be inquired into. I have already ſhown, that almoſt all the oxydable and acidifiable radicals from the mineral kingdom are ſimple, and that, on the contrary, there hardly exiſts any radical in the vegetable, and more eſpecially in the animal kingdom, but is compoſed of at leaſt two ſubſtances, hydrogen and charcoal, and that azote and phoſphorus are frequently united to theſe, by which we have compound radicals of two, three, and four baſes or ſimple elements united.

From

From theſe obſervations, it appears that the vegetable and animal oxyds and acids may differ from each other in three ſeveral ways: 1ſt, According to the number of ſimple acidifiable elements of which their radicals are compoſed: 2dly, According to the proportions in which theſe are combined together: And, 3dly, According to their different degrees of oxygenation: Which circumſtances are more than ſufficient to explain the great variety which nature produces in theſe ſubſtances. It is not at all ſurpriſing, after this, that moſt of the vegetable acids are convertible into each other, nothing more being requiſite than to change the proportions of the hydrogen and charcoal in their compoſition, and to oxygenate them in a greater or leſſer degree. This has been done by Mr Crell in ſome very ingenious experiments, which have been verified and extended by Mr Haſſenfratz. From theſe it appears, that charcoal and hydrogen, by a firſt oxygenation, produce tartarous acid, oxalic acid by a ſecond degree, and acetous or acetic acid by a third, or higher oxygenation; only, that charcoal ſeems to exiſt in a rather ſmaller proportion in the acetous and acetic acids. The citric and malic acids differ little from the preceding acids.

Ought we then to conclude that the oils are the radicals of the vegetable and animal acids? I have already expreſſed my doubts upon this ſubject:

ſubject: 1ſt, Although the oils appear to be formed of nothing but hydrogen and charcoal, we do not know if theſe are in the preciſe proportion neceſſary for conſtituting the radicals of the acids: 2dly, Since oxygen enters into the compoſition of theſe acids equally with hydrogen and charcoal, there is no more reaſon for ſuppoſing them to be compoſed of oil rather than of water or of carbonic acid. It is true that they contain the materials neceſſary for all theſe combinations, but then theſe do not take place in the common temperature of the atmoſphere; all the three elements remain combined in a ſtate of equilibrium, which is readily deſtroyed by a temperature only a little above that of boiling water *.

---

* See Part I. Chap. XII. upon this ſubject.—A.

TABLE *of the Binary Combinations of Azote with the Simple Subſtances.*

Simple Subſtances.	*Reſults of the Combinations.*	
	New Nomenclature.	*Old Nomenclature.*
Caloric	Azotic gas	Phlogiſticated air, or Mephitis.
Hydrogen	Ammoniac	Volatile alkali.
Oxygen	Nitrous oxyd	Baſe of Nitrous gas.
	Nitrous acid	Smoaking nitrous acid.
	Nitric acid	Pale nitrous acid.
	Oxygenated nitric acid	Unknown.
Charcoal	This combination is hitherto unknown; ſhould it ever be diſcovered, it will be called, according to the principles of our nomenclature, Azuret of Charcoal. Charcoal diſſolves in azotic gas, and forms carbonated azotic gas.	
Phoſphorus.	Azuret of phoſphorus.	Still unknown.
Sulphur	Azuret of ſulphur. Still unknown. We know that ſulphur diſſolves in azotic gas, forming ſulphurated azotic gas.	
Compound radicals	Azote combines with charcoal and hydrogen, and ſometimes with phoſphorus, in the compound oxydable and acidifiable baſes, and is generally contained in the radicals of the animal acids.	
Metallic ſubſtances	Such combinations are hitherto unknown; if ever diſcovered, they will form metallic azurets, as azuret of gold, of ſilver, &c.	
Lime Magneſia Barytes Argill Potaſh Soda	Entirely unknown. If ever diſcovered, they will form azuret of lime, azuret of magneſia, &c.	

SECT. VI.—*Obſervations upon the Combinations of Azote with the Simple Subſtances.*

Azote is one of the moſt abundant elements; combined with caloric it forms azotic gas, or mephitis, which compoſes nearly two thirds of the atmoſphere. This element is always in the ſtate of gas in the ordinary preſſure and temperature, and no degree of compreſſion or of cold has been hitherto capable of reducing it either to a ſolid or liquid form. This is likewiſe one of the eſſential conſtituent elements of animal bodies, in which it is combined with charcoal and hydrogen, and ſometimes with phoſphorus; theſe are united together by a certain portion of oxygen, by which they are formed into oxyds or acids according to the degree of oxygenation. Hence the animal ſubſtances may be varied, in the ſame way with vegetables, in three different manners: 1ſt, According to the number of elements which enter into the compoſition of the baſe or radical: 2dly, According to the proportions of theſe elements: 3dly, According to the degree of oxygenation.

When combined with oxygen, azote forms the nitrous and nitric oxyds and acids; when with hydrogen, ammoniac is produced. Its combinations with the other ſimple elements are

are very little known; to theſe we give the name of Azurets, preſerving the termination in *uret* for all nonoxygenated compounds. It is extremely probable that all the alkaline ſubſtances may hereafter be found to belong to this genus of azurets.

The azotic gas may be procured from atmoſpheric air, by abſorbing the oxygen gas which is mixed with it by means of a ſolution of ſulphuret of potaſh, or ſulphuret of lime. It requires twelve or fifteen days to complete this proceſs, during which time the ſurface in contact muſt be frequently renewed by agitation, and by breaking the pellicle which forms on the top of the ſolution. It may likewiſe be procured by diſſolving animal ſubſtances in dilute nitric acid very little heated. In this operation the azote is diſengaged in form of gas, which we receive under bell glaſſes filled with water in the pneumato-chemical apparatus. We may procure this gas by deflagrating nitre with charcoal, or any other combuſtible ſubſtance; when with charcoal, the azotic gas is mixed with carbonic acid gas, which may be abſorbed by a ſolution of cauſtic alkali, or by lime water, after which the azotic gas remains pure. We can procure it in a fourth manner from combinations of ammoniac with metallic oxyds, as pointed out by Mr de Fourcroy: The hydrogen of the ammoniac combines with the oxygen of the

oxyd,

oxyd, and forms water, whilſt the azote being left free eſcapes in form of gas.

The combinations of azote were but lately diſcovered: Mr Cavendiſh firſt obſerved it in nitrous gas and acid, and Mr Berthollet in ammoniac and the pruſſic acid. As no evidence of its decompoſition has hitherto appeared, we are fully entitled to conſider azote as a ſimple elementary ſubſtance.

TABLE *of the Binary Combinations of Hydrogen with Simple Subſtances.*

Simple Subſtances.	*Reſulting Compounds.*	
	New Nomenclature.	*Old Names.*
Caloric	Hydrogen gas	Inflammable air.
Azote	Ammoniac	Volatile Alkali.
Oxygen	Water	Water.
Sulphur	Hydruret of ſulphur, or ſulphuret of hydrogen	Hitherto unknown *.
Phoſphorus	Hydruret of phoſphorus, or phoſphuret of hydrogen	
Charcoal	Hydro-carbonous, or carbono-hydrous radicals †	Not known till lately.
Metallic ſubſtances, as iron, &c.	Metallic hydrurets ‡, as hydruret of iron, &c.	Hitherto unknown.

---

* Theſe combinations take place in the ſtate of gas, and form, reſpectively, ſulphurated and phoſphorated oxygen gas.—A.

† This combination of hydrogen with charcoal includes the fixed and volatile oils, and forms the radicals of a conſiderable part of the vegetable and animal oxyds and acids. When it takes place in the ſtate of gas it forms carbonated hydrogen gas.—A.

‡ None of theſe combinations are known, and it is probable that they cannot exiſt, at leaſt in the uſual temperature of the atmoſphere, owing to the great affinity of hydrogen for caloric.—A.

SECT. VII.—*Obſervations upon Hydrogen, and its Combinations with Simple Subſtances.*

Hydrogen, as its name expreſſes, is one of the conſtituent elements of water, of which it forms fifteen hundredth parts by weight, combined with eighty-five hundredth parts of oxygen. This ſubſtance, the properties and even exiſtence of which was unknown till lately, is very plentifully diſtributed in nature, and acts a very conſiderable part in the proceſſes of the animal and vegetable kingdoms. As it poſſeſſes ſo great affinity with caloric as only to exiſt in the ſtate of gas, it is conſequently impoſſible to procure it in the concrete or liquid ſtate, independent of combination.

To procure hydrogen, or rather hydrogen gas, we have only to ſubject water to the action of a ſubſtance with which oxygen has greater affinity than it has to hydrogen; by this means the hydrogen is ſet free, and, by uniting with caloric, aſſumes the form of hydrogen gas. Red hot iron is uſually employed for this purpoſe: The iron, during the proceſs, becomes oxydated, and is changed into a ſubſtance reſembling the iron ore from the iſland of Elba. In this ſtate of oxyd it is much leſs attractible by the

the magnet, and diſſolves in acids without efferveſcence.

Charcoal, in a red heat, has the ſame power of decompoſing water, by attracting the oxygen from its combination with hydrogen. In this proceſs carbonic acid gas is formed, and mixes with the hydrogen gas, but is eaſily ſeparated by means of water or alkalies, which abſorb the carbonic acid, and leave the hydrogen gas pure. We may likewiſe obtain hydrogen gas by diſſolving iron or zinc in dilute ſulphuric acid. Theſe two metals decompoſe water very ſlowly, and with great difficulty, when alone, but do it with great eaſe and rapidity when aſſiſted by ſulphuric acid; the hydrogen unites with caloric during the proceſs, and is diſengaged in form of hydrogen gas, while the oxygen of the water unites with the metal in the form of oxyd, which is immediately diſſolved in the acid, forming a ſulphat of iron or of zinc.

Some very diſtinguiſhed chemiſts conſider hydrogen as the *phlogiſton* of Stahl; and as that celebrated chemiſt admitted the exiſtence of phlogiſton in ſulphur, charcoal, metals, &c. they are of courſe obliged to ſuppoſe that hydrogen exiſts in all theſe ſubſtances, though they cannot prove their ſuppoſition; even if they could, it would not avail much, ſince this diſengagement of hydrogen is quite inſufficient to explain the phenomena of calcination and combuſtion.

We muſt always recur to the examination of this queſtion, " Are the heat and light, which are diſengaged during the different ſpecies of combuſtion, furniſhed by the burning body, or by the oxygen which combines in all theſe operations?" And certainly the ſuppoſition of hydrogen being diſengaged throws no light whatever upon this queſtion. Beſides, it belongs to thoſe who make ſuppoſitions to prove them; and, doubtleſs, a doctrine which without any ſuppoſition explains the phenomena as well, and as naturally, as theirs does by ſuppoſition, has at leaſt the advantage of greater ſimplicity *.

---

* Thoſe who wiſh to ſee what has been ſaid upon this great chemical queſtion by Meſſrs de Morveau, Berthollet, De Fourcroy, and myſelf, may conſult our tranſlation of Mr Kirwan's Eſſay upon Phlogiſton.—A.

TABLE *of the Binary Combinations of Sulphur with Simple Subſtances.*

Simple Subſtances.	*Reſulting Compounds.*	
	New Nomenclature.	*Old Nomenclature.*
Caloric	Sulphuric gas	
Oxygen	Oxyd of ſulphur Sulphurous acid Sulphuric acid	Soft ſulphur. Sulphureous acid. Vitriolic acid.
Hydrogen	Sulphuret of hydrogen	Unknown Combinations.
Azote	azote	
Phoſphorus	phoſphorus	
Charcoal	charcoal	
Antimony	antimony	Crude antimony.
Silver	ſilver	
Arſenic	arſenic	Orpiment, realgar.
Biſmuth	biſmuth	
Cobalt	cobalt	
Copper	copper	Copper pyrites.
Tin	tin	
Iron	iron	Iron pyrites.
Manganeſe	manganeſe	
Mercury	mercury	Ethiops mineral, cinnabar.
Molybdena	molybdena	
Nickel	nickel	
Gold	gold	
Platina	platina	
Lead	lead	Galena.
Tungſtein	tungſtein	
Zinc	zinc	Blende.
Potaſh	potaſh	Alkaline liver of ſulphur with fixed vegetable alkali.
Soda	ſoda	Alkaline liver of ſulphur with fixed mineral alkali.
Ammoniac	ammoniac	Volatile liver of ſulphur, ſmoaking liquor of Boyle.
Lime	lime	Calcareous liver of ſulphur.
Magneſia	magneſia	Magneſian liver of ſulphur.
Barytes	barytes	Barytic liver of ſulphur.
Argill	argill	Yet unknown.

SECT. VIII.—*Obſervations on Sulphur, and its Combinations.*

Sulphur is a combuſtible ſubſtance, having a very great tendency to combination; it is naturally in a ſolid ſtate in the ordinary temperature, and requires a heat ſomewhat higher than boiling water to make it liquify. Sulphur is formed by nature in a conſiderable degree of purity in the neighbourhood of volcanos; we find it likewiſe, chiefly in the ſtate of ſulphuric acid, combined with argill in aluminous ſchiſtus, with lime in gypſum, &c. From theſe combinations it may be procured in the ſtate of ſulphur, by carrying off its oxygen by means of charcoal in a red heat; carbonic acid is formed, and eſcapes in the ſtate of gas; the ſulphur remains combined with the clay, lime, &c. in the ſtate of ſulphuret, which is decompoſed by acids; the acid unites with the earth into a neutral ſalt, and the ſulphur is precipitated.

TABLE *of the Binary Combinations of Phoſphorus with the Simple Subſtances.*

Simple Subſtances.	*Reſulting Compounds.*
Caloric - -	Phoſphoric gas.
Oxygen - -	Oxyd of phoſphorus.
	Phoſphorous acid.
	Phoſphoric acid.
Hydrogen - -	Phoſphuret of hydrogen.
Azote - -	Phoſphuret of azote.
Sulphur - -	Phoſphuret of Sulphur.
Charcoal - -	Phoſphuret of charcoal.
Metallic ſubſtances	Phoſphuret of metals [*].
Potaſh - -	Phoſphuret of Potaſh, Soda, &c. [†]
Soda - -	
Ammoniac - -	
Lime - -	
Barytes - -	
Magneſia - -	
Argill - -	

SECT.

---

[*] Of all theſe combinations of phoſphorus with metals, that with iron only is hitherto known, forming the ſubſtance formerly called Siderite; neither is it yet aſcertained whether, in this combination, the phoſphorus be oxygenated or not.—A.

[†] Theſe combinations of phoſphorus with the alkalies and earths are not yet known; and, from the experiments of Mr Gengembre, they appear to be impoſſible.—A.

SECT. IX.—*Obſervations upon Phoſphorus, and its Combinations.*

Phoſphorus is a ſimple combuſtible ſubſtance, which was unknown to chemiſts till 1667, when it was diſcovered by Brandt, who kept the proceſs ſecret; ſoon after Kunkel found out Brandt's method of preparation, and made it public. It has been ever ſince known by the name of Kunkel's phoſphorus. It was for a long time procured only from urine; and, though Homberg gave an account of the proceſs in the Memoirs of the Academy for 1692, all the philoſophers of Europe were ſupplied with it from England. It was firſt made in France in 1737, before a committee of the Academy at the Royal Garden. At preſent it is procured in a more commodious and more oeconomical manner from animal bones, which are real calcareous phoſphats, according to the proceſs of Meſſrs Gahn, Scheele, Rouelle, &c. The bones of adult animals being calcined to whiteneſs, are pounded, and paſſed through a fine ſilk ſieve; pour upon the fine powder a quantity of dilute ſulphuric acid, leſs than is ſufficient for diſſolving the whole. This acid unites with the calcareous earth of the bones into a ſulphat of lime, and the phoſphoric acid remains free in the liquor. The liquid is is decanted off, and the reſiduum waſhed with boiling water; this water which has been uſed to waſh out the adhering acid is joined with what was before decanted off, and the whole is gradually evaporated; the diſſolved ſulphat of lime criſtallizes in form of ſilky threads, which are removed, and by continuing the evaporation we procure the phoſphoric acid under the appearance of a white pellucid glaſs. When this is powdered, and mixed with one third its weight of charcoal, we procure very pure phoſphorus by ſublimation. The phoſphoric acid, as procured by the above proceſs, is never ſo pure as that obtained by oxygenating pure phoſphorus either by combuſtion or by means of nitric acid; wherefore this latter ſhould always be employed in experiments of reſearch.

Phoſphorus is found in almoſt all animal ſubſtances, and in ſome plants which give a kind of animal analyſis. In all theſe it is uſually combined with charcoal, hydrogen, and azote, forming very compound radicals, which are, for the moſt patt, in the ſtate of oxyds by a firſt degree of union with oxygen. The diſcovery of Mr Haſſenfratz, of phoſphorus being contained in charcoal, gives reaſon to ſuſpect that it is more common in the vegetable kingdom than has generally been ſuppoſed: It is certain, that, by proper proceſſes, it may be procured from every individual of ſome of the families of plants.

As

As no experiment has hitherto given reaſon to ſuſpect that phoſphorus is a compound body, I have arranged it with the ſimple or elementary ſubſtances. It takes fire at the temperature of 32° (104°) of the thermometer.

TABLE *of the Binary Combinations of Charcoal.*

Simple Subſtances.	*Reſulting Compounds.*	
Oxygen	Oxyd of charcoal	Unknown.
	Carbonic acid	Fixed air, chalky acid.
Sulphur	Carburet of ſulphur	Unknown.
Phoſphorus	Carburet of phoſphorus	
Azote	Carburet of azote	
Hydrogen	Carbono-hydrous radical	
	Fixed and volatile oils	
Metallic ſubſtances	Carburets of metals	Of theſe only the carburets of iron and zinc are known, and were formerly called Plumbago.
Alkalies and earths	Carburet of potaſh, &c.	Unknown.

SECT. X.—*Obſervations upon Charcoal, and its Combinations with Simple Subſtances.*

As charcoal has not been hitherto decompoſed, it muſt, in the preſent ſtate of our knowledge, be conſidered as a ſimple ſubſtance. By modern experiments it appears to exiſt ready formed in vegetables; and I have already remarked, that, in theſe, it is combined with hydrogen, ſometimes with azote and phoſphorus, forming compound radicals, which may be changed into oxyds or acids according to their degree of oxygenation.

To obtain the charcoal contained in vegetable or animal ſubſtances, we ſubject them to the action of fire, at firſt moderate, and afterwards very ſtrong, on purpoſe to drive off the laſt portions of water, which adhere very obſtinately to the charcoal. For chemical purpoſes, this is uſually done in retorts of ſtone-ware or porcelain, into which the wood, or other matter, is introduced, and then placed in a reverberatory furnace, raiſed gradually to its greateſt heat: The heat volatilizes, or changes into gas, all the parts of the body ſuſceptible of combining with caloric into that form, and the charcoal, being more fixed in its nature, remains in the retort combined

combined with a little earth and ſome fixed ſalts.

In the buſineſs of charring wood, this is done by a leſs expenſive proceſs. The wood is diſpoſed in heaps, and covered with earth, ſo as to prevent the acceſs of any more air than is abſolutely neceſſary for ſupporting the fire, which is kept up till all the water and oil is driven off; after which the fire is extinguiſhed by ſhutting up all the air-holes.

We may analyſe charcoal either by combuſtion in air, or rather in oxygen gas, or by means of nitric acid. In either caſe we convert it into carbonic acid, and ſometimes a little potaſh and ſome neutral ſalts remain. This analyſis has hitherto been but little attended to by chemiſts; and we are not even certain if potaſh exiſts in charcoal before combuſtion, or whether it be formed by means of ſome unknown combination during that proceſs.

SECT. XI.—*Obſervations upon the Muriatic, Fluoric, and Boracic Radicals, and their Combinations.*

As the combinations of theſe ſubſtances, either with each other, or with the other combuſtible bodies, are hitherto entirely unknown, we have not attempted to form any table for their nomenclature. We only know that theſe radicals are ſuſceptible of oxygenation, and of forming the muriatic, fluoric, and boracic acids, and that in the acid ſtate they enter into a number of combinations, to be afterwards detailed. Chemiſtry has hitherto been unable to diſoxygenate any of them, ſo as to produce them in a ſimple ſtate. For this purpoſe, ſome ſubſtance muſt be employed to which oxygen has a ſtronger affinity than to their radicals, either by means of ſingle affinity, or by double elective attraction. All that is known relative to the origin of the radicals of theſe acids will be mentioned in the ſections ſet apart for conſidering their combinations with the ſalifiable baſes.

SECT. XII.—*Obſervations upon the Combinations of Metals with each other.*

Before cloſing our account of the ſimple or elementary ſubſtances, it might be ſuppoſed neceſſary to give a table of alloys or combinations of metals with each other; but, as ſuch a table would be both exceedingly voluminous and very unſatisfactory, without going into a ſeries of experiments not yet attempted, I have thought it adviſeable to omit it altogether. All that is neceſſary to be mentioned is, that theſe alloys ſhould be named according to the metal in largeſt proportion in the mixture or combination; thus the term *alloy of gold and ſilver*, or gold alloyed with ſilver, indicates that gold is the predominating metal.

Metallic alloys, like all other combinations, have a point of ſaturation. It would even appear, from the experiments of Mr de la Briche, that they have two perfectly diſtinct degrees of ſaturation.

TABLE *of the Combinations of Azote in the ſtate of Nitrous Acid with the Salifiable Baſes, arranged according to the affinities of theſe Baſes with the Acid.*

Names of the baſes.	*Names of the neutral ſalts.* *New nomenclature.*	*Notes.*
Barytes	Nitrite of barytes.	Theſe ſalts are only known of late, and have received no particular name in the old nomenclature.
Potaſh	potaſh.	
Soda	ſoda.	
Lime	lime.	
Magneſia	magneſia.	
Ammoniac	ammoniac.	
Argill	argill.	
Oxyd of zinc	zinc.	As metals diſſolve both in nitrous and nitric acids, metallic ſalts muſt of conſequence be formed having different degrees of oxygenation. Thoſe wherein the metal is leaſt oxygenated muſt be called Nitrites, when more ſo, Nitrats; but the limits of this diſtinction are difficultly aſcertainable. The older chemiſts were not acquainted with any of theſe ſalts.
iron	iron.	
mangaueſe	manganeſe.	
cobalt	cobalt.	
nickel	nickel.	
lead	lead.	
tin	tin.	
copper	copper.	
biſmuth	biſmuth.	
antimony	antimony.	
arſenic	arſenic.	
mercury	mercury.	
ſilver	It is extremely probable that gold, ſilver, and platina only form nitrats, and cannot ſubſiſt in the ſtate of nitrites.	
gold		
platina		

TABLE *of the Combinations of Azote, completely ſaturated with Oxygen, in the ſtate of Nitric Acid, with the Salifiable Baſes, in the order of the affinity with the Acid.*

Baſes.	*Names of the reſulting neutral ſalts.*	
	New nomenclature.	*Old nomenclature.*
Barytes	Nitrat of barytes	Nitre, with a baſe of heavy earth.
Potaſh	potaſh	Nitre, ſaltpetre. Nitre with baſe of potaſh.
Soda	ſoda	Quadrangular nitre. Nitre with baſe of mineral alkali.
Lime	lime	Calcareous nitre. Nitre with calcareous baſe. Mother water of nitre, or ſaltpetre.
Magneſia	magneſia	Magneſian nitre. Nitre with baſe of magneſia.
Ammoniac	ammoniac	Ammoniacal nitre.
Argill	argill	Nitrous alum. Argillaceous nitre. Nitre with baſe of earth of alum.
Oxyd of zinc	zinc	Nitre of zinc.
iron	iron	Nitre of iron. Martial nitre. Nitrated iron.
mangaueſe	manganeſe	Nitre of manganeſe.
cobalt	cobalt	Nitre of cobalt.
nickel	nickel	Nitre of nickel.
lead	lead	Saturnine nitre. Nitre of lead.
tin	tin	Nitre of tin.
copper	copper	Nitre of copper or of Venus.
biſmuth	biſmuth	Nitre of biſmuth.
antimony	antimony	Nitre of antimony.
arſenic	arſenic	Arſenical nitre.
mercury	mercury	Mercurial nitre.
ſilver	ſilver	Nitre of ſilver or luna. Lunar cauſtic.
gold	gold	Nitre of gold.
platina	platina	Nitre of platina.

SECT.

SECT. XIII.—*Obſervations upon the Nitrous and Nitric Acids, and their Combinations.*

The nitrous and nitric acids are procured from a neutral ſalt long known in the arts under the name of *ſaltpetre*. This ſalt is extracted by lixiviation from the rubbiſh of old buildings, from the earth of cellars, ſtables, or barns, and in general of all inhabited places. In theſe earths the nitric acid is uſually combined with lime and magneſia, ſometimes with potaſh, and rarely with argill. As all theſe ſalts, excepting the nitrat of potaſh, attract the moiſture of the air, and conſequently would be difficultly preſerved, advantage is taken, in the manufactures of ſaltpetre and the royal refining-houſe, of the greater affinity of the nitric acid to potaſh than theſe other baſes, by which means the lime, magneſia, and argill, are precipitated, and all theſe nitrats are reduced to the nitrat of potaſh or ſaltpetre *.

The nitric acid is procured from this ſalt by diſtillation, from three parts of pure ſaltpetre decompoſed by one part of concentrated ſulphuric

---

* Saltpetre is likewiſe procured in large quantities by lixiviating the natural ſoil in ſome parts of Bengal, and of the Ruſſian Ukrain.—E.

phuric acid, in a retort with Woulfe's apparatus, (Pl. IV. fig. 1.) having its bottles half filled with water, and all its joints carefully luted. The nitrous acid paſſes over in form of red vapours ſurcharged with nitrous gas, or, in other words, not ſaturated with oxygen. Part of the acid condenſes in the recipient in form of a dark orange red liquid, while the reſt combines with the water in the bottles. During the diſtillation, a large quantity of oxygen gas eſcapes, owing to the greater affinity of oxygen to caloric, in a high temperature, than to nitrous acid, though in the uſual temperature of the atmoſphere this affinity is reverſed. It is from the diſengagement of oxygen that the nitric acid of the neutral ſalt is in this operation converted into nitrous acid. It is brought back to the ſtate of nitric acid by heating over a gentle fire, which drives off the ſuperabundant nitrous gas, and leaves the nitric acid much diluted with water.

Nitric acid is procurable in a more concentrated ſtate, and with much leſs loſs, by mixing very dry clay with ſaltpetre. This mixture is put into an earthern retort, and diſtilled with a ſtrong fire. The clay combines with the potaſh, for which it has great affinity, and the nitric acid paſſes over, ſlightly impregnated with nitrous gas. This is eaſily diſengaged by heating the acid gently in a retort, a ſmall quantity of of nitrous gas paſſes over into the recipient; and very pure concentrated nitric acid remains in the retort.

We have already ſeen that azote is the nitric radical. If to 20½ parts, by weight, of azote 43½ parts of oxygen be added, 64 parts of nitrous gas are formed; and, if to this we join 36 additional parts of oxygen, 100 parts of nitric acid reſult from the combination. Intermediate quantities of oxygen between theſe two extremes of oxygenation produce different ſpecies of nitrous acid, or, in other words, nitric acid leſs or more impregnated with nitrous gas. I aſcertained the above proportions by means of decompoſition; and, though I cannot anſwer for their abſolute accuracy, they cannot be far removed from truth. Mr Cavendiſh, who firſt ſhowed by ſynthetic experiments that azote is the baſe of nitric acid, gives the proportions of azote a little larger than I have done; but, as it is not improbable that he produced the nitrous acid and not the nitric, that circumſtance explains in ſome degree the difference in the reſults of our experiments.

As, in all experiments of a philoſophical nature, the utmoſt poſſible degree of accuracy is required, we muſt procure the nitric acid for experimental purpoſes, from nitre which has been previouſly purified from all foreign matter. If, after diſtillation, any ſulphuric acid is ſuſpected

ſpected in the nitric acid, it is eaſily ſeparated by dropping in a little nitrat of barytes, ſo long as any precipitation takes place; the ſulphuric acid, from its greater affinity, attracts the barytes, and forms with it an inſoluble neutral ſalt, which falls to the bottom. It may be purified in the ſame manner from muriatic acid, by dropping in a little nitrat of ſilver ſo long as any precipitation of muriat of ſilver is produced. When theſe two precipitations are finiſhed, diſtill off about ſeven-eighths of the acid by a gentle heat, and what comes over is in the moſt perfect degree of purity.

The nitric acid is one of the moſt prone to combination, and is at the ſame time very eaſily decompoſed. Almoſt all the ſimple ſubſtances, with the exception of gold, ſilver, and platina, rob it leſs or more of its oxygen; ſome of them even decompoſe it altogether. It was very anciently known, and its combinations have been more ſtudied by chemiſts than thoſe of any other acid. Theſe combinations were named *nitres* by Meſſrs Macquer and Beaumé; but we have changed their names to nitrats and nitrites, according as they are formed by nitric or by nitrous acid, and have added the ſpecific name of each particular baſe, to diſtinguiſh the ſeveral combinations from each other.

TABLE *of the Combinations of Sulphuric Acid with the Saliſiable Baſes, in the order of affinity.*

Names of the baſes.	*Reſulting compounds.*	
	New nomenclature.	*Old nomenclature.*
Barytes	Sulphat of barytes	Heavy ſpar. Vitriol of heavy earth.
Potaſh	potaſh	Vitriolated tartar. Sal de duobus. Arcanum duplicatam.
Soda	ſoda	Glauber's ſalt.
Lime	lime	Selenite, gypſum, calcareous vitriol.
Magneſia	magneſia	Epſom ſalt, ſedlitz ſalt, magneſian vitriol.
Ammoniac	ammoniac	Glauber's ſecret ſal ammoniac.
Argill	argill	Alum.
Oxyd of zinc	zinc	White vitriol, goſlar vitriol, white coperas, vitriol of zinc.
iron	iron	Green coperas, green vitriol, martial vitriol, vitriol of iron.
manganeſe	manganeſe	Vitriol of manganeſe.
cobalt	cobalt	Vitriol of cobalt.
nickel	nickel	Vitriol of nickel.
lead	lead	Vitriol of lead.
tin	tin	Vitriol of tin.
copper	copper	Blue coperas, blue vitriol, Roman vitriol, vitriol of copper.
biſmuth	biſmuth	Vitriol of biſmuth.
antimony	antimony	Vitriol of antimony.
arſenic	arſenic	Vitriol of arſenic.
mercury	mercury	Vitriol of mercury.
ſilver	ſilver	Vitriol of ſilver.
gold	gold	Vitriol of gold.
platina	platina	Vitriol of platina.

SECT. XIV.—*Obſervations upon Sulphuric Acid and its Combinations.*

For a long time this acid was procured by diſtillation from ſulphat of iron, in which ſulphuric acid and oxyd of iron are combined, according to the proceſs deſcribed by Baſil Valentine in the fifteenth century; but, in modern times, it is procured more oeconomically by the combuſtion of ſulphur in proper veſſels. Both to facilitate the combuſtion, and to aſſiſt the oxygenation of the ſulphur, a little powdered ſaltpetre, nitrat of potaſh, is mixed with it; the nitre is decompoſed, and gives out its oxygen to the ſulphur, which contributes to its converſion into acid. Notwithſtanding this addition, the ſulphur will only continue to burn in cloſe veſſels for a limited time; the combination ceaſes, becauſe the oxygen is exhauſted, and the air of the veſſels reduced almoſt to pure azotic gas, and becauſe the acid itſelf remains long in the ſtate of vapour, and hinders the progreſs of combuſtion.

In the manufactories for making ſulphuric acid in the large way, the mixture of nitre and ſulphur is burnt in large cloſe built chambers lined with lead, having a little water at the bottom for facilitating the condenſation of the vapours,

pours. Afterwards, by diſtillation in large retorts with a gentle heat, the water paſſes over, ſlightly impregnated with acid, and the ſulphuric acid remains behind in a concentrated ſtate. It is then pellucid, without any flavour, and nearly double the weight of an equal bulk of water. This proceſs would be greatly facilitated, and the combuſtion much prolonged, by introducing freſh air into the chambers, by means of ſeveral pairs of bellows directed towards the flame of the ſulphur, and by allowing the nitrous gas to eſcape through long ſerpentine canals, in contact with water, to abſorb any ſulphuric or ſulphurous acid gas it might contain.

By one experiment, Mr Berthollet found that 69 parts of ſulphur in combuſtion, united with 31 parts of oxygen, to form 100 parts of ſulphuric acid ; and, by another experiment, made in a different manner, he calculates that 100 parts of ſulphuric acid conſiſts of 72 parts ſulphur, combined with 28 parts of oxygen, all by weight.

This acid, in common with every other, can only diſſolve metals when they have been previouſly oxydated ; but moſt of the metals are capable of decompoſing a part of the acid, ſo as to carry off a ſufficient quantity of oxygen, to render themſelves ſoluble in the part of the acid which remains undecompoſed. This happens with ſilver, mercury, iron, and zinc, in boiling concentrated

concentrated ſulphuric acid; they become firſt oxydated by decompoſing part of the acid, and then diſſolve in the other part; but they do not ſufficiently diſoxygenate the decompoſed part of the acid to reconvert it into ſulphur; it is only reduced to the ſtate of ſulphurous acid, which, being volatiliſed by the heat, flies off in form of ſulphurous acid gas.

Silver, mercury, and all the other metals except iron and zinc, are inſoluble in diluted ſulphuric acid, becauſe they have not ſufficient affinity with oxygen to draw it off from its combination either with the ſulphur, the ſulphurous acid, or the hydrogen; but iron and zinc, being aſſiſted by the action of the acid, decompoſe the water, and become oxydated at its expence, without the help of heat.

TABLE *of the Combinations of the Sulphurous Acid with the Salifiable Baſes, in the order of affinity.*

Names of the Baſes.	*Names of the Neutral Salts.*
Barytes	Sulphite of barytes.
Potaſh	potaſh.
Soda	ſoda.
Lime	lime.
Magneſia	magneſia.
Ammoniac	ammoniac.
Argill	argill.
Oxyd of zinc	zinc.
iron	iron.
manganeſe	manganeſe.
cobalt	cobalt.
nickel	nickel.
lead	lead.
tin	tin.
copper	copper.
biſmuth	biſmuth.
antimony	antimony.
arſenic	arſenic.
mercury	mercury.
ſilver	ſilver.
gold	gold.
platina	platina.

SECT.

Note.——The only one of theſe ſalts known to the old chemiſts was the ſulphite of potaſh, under the name of *Stahl's ſulphureous ſalt.* So that, before our new nomenclature, theſe compounds muſt have been named *Stahl's ſulphureous ſalt,* having baſe of fixed vegetable alkali, and ſo of the reſt.

In this Table we have followed Bergman's order of affinity of the ſulphuric acid, which is the ſame in regard to the earths and alkalies, but it is not certain if the order be the ſame for the metallic oxyds.—A.

SECT. XV.—*Obſervations upon Sulphurous Acid, and its Combinations.*

The ſulphurous acid is formed by the union of oxygen with ſulphur by a leſſer degree of oxygenation than the ſulphuric acid. It is procurable either by burning ſulphur ſlowly, or by diſtilling ſulphuric acid from ſilver, antimony, lead, mercury, or charcoal; by which operation a part of the oxygen quits the acid, and unites to theſe oxydable baſes, and the acid paſſes over in the ſulphurous ſtate of oxygenation. This acid, in the common preſſure and temperature of the air, can only exiſt in form of gas; but it appears, from the experiments of Mr Clouet, that, in a very low temperature, it condenſes, and becomes fluid. Water abſorbs a great deal more of this gas than of carbonic acid gas, but much leſs than it does of muriatic acid gas.

That the metals cannot be diſſolved in acids without being previouſly oxydated, or by procuring oxygen, for that purpoſe, from the acids during ſolution, is a general and well eſtabliſhed fact, which I have perhaps repeated too often. Hence, as ſulphurous acid is already deprived of great part of the oxygen neceſſary for forming the ſulphuric acid, it is more diſpoſed to recover oxygen, than to furniſh it to the greateſt part of the metals; and, for this reaſon, it cannot diſſolve them, unleſs previouſly oxydated by other means. From the ſame principle it is that the metallic oxyds diſſolve without effervefcence, and with great facility, in ſulphurous acid. This acid, like the muriatic, has even the property of diſſolving metallic oxyds ſurcharged with oxygn, and conſequently inſoluble in ſulphuric acid, and in this way forms true ſulphats. Hence we might be led to conclude that there are no metallic ſulphites, were it not that the phenomena which accompany the ſolution of iron, mercury, and ſome other metals, convince us that theſe metallic ſubſtances are ſuſceptible of two degrees of oxydation, during their ſolution in acids. Hence the neutral ſalt in which the metal is leaſt oxydated muſt be named *ſulphite*, and that in which it is fully oxydated muſt be called *ſulphat*. It is yet unknown whether this diſtinction is applicable to any of the metallic ſulphats, except thoſe of iron and mercury.

TABLE *of the Combinations of Phoſphorous and Phoſphoric Acids, with the Saliſiable Baſes, in the Order of Affinity.*

Names of the Baſes.	*Names of the Neutral Salts formed by*	
	Phoſphorous Acid,	*Phoſphoric Acid.*
Lime	Phoſphites of† lime	Phoſphats of ‡ lime.
Barytes	barytes	barytes.
Magneſia	magneſia	magneſia.
Potaſh	potaſh	potaſh.
Soda	ſoda	ſoda.
Ammoniac	ammoniac	ammoniac.
Argill	argill	argill.
Oxyds of *		
zinc	zinc	zinc.
iron	iron	iron.
manganeſe	manganeſe	manganeſe.
cobalt	cobalt	cobalt.
nickel	nickel	nickel.
lead	lead	lead.
tin	tin	tin.
copper	copper	copper.
biſmuth	biſmuth	biſmuth.
antimony	antimony	antimony.
arſenic	arſenic	arſenic.
mercury	mercury	mercury.
ſilver	ſilver	ſilver.
gold	gold.	gold.
platina	platina	platina.

---

[*] The exiſtence of metallic phoſphites ſuppoſes that metals are ſuſceptible of ſolution in phoſphoric acid at different degrees of oxygenation, which is not yet aſcertained.—A.

[†] All the phoſphites were unknown till lately, and conſequently have not hitherto received names.—A.

[‡] The greater part of the phoſphats were only diſcovered of late, and have not yet been named.—A.

Sect. XVI.—*Obſervations upon Phoſphorous and Phoſporic Acids, and their Combinations.*

Under the article Phoſphorus, Part II. Sect. X. we have already given a hiſtory of the diſcovery of that ſingular ſubſtance, with ſome obſervations upon the mode of its exiſtence in vegetable and animal bodies. The beſt method of obtaining this acid in a ſtate of purity is by burning well purified phoſphorus under bell-glaſſes, moiſtened on the inſide with diſtilled water; during combuſtion it abſorbs twice and a half its weight of oxygen; ſo that 100 parts of phoſphoric acid is compoſed of 28½ parts of phoſphorus united to 71½ parts of oxygen. This acid may be obtained concrete, in form of white flakes, which greedily attract the moiſture of the air, by burning phoſphorus in a dry glaſs over mercury.

To obtain phoſphorous acid, which is phoſphorus leſs oxygenated than in the ſtate of phoſphoric acid, the phoſphorus muſt be burnt by a very ſlow ſpontaneous combuſtion over a glaſs-funnel leading into a cryſtal phial; after a few days, the phoſphorus is found oxygenated, and the phoſphorous acid, in proportion as it forms, has attracted moiſture from the air, and dropped into the phial. The phoſphorous

rous acid is readily changed into phoſphoric acid by expoſure for a long time to the free air; it abſorbs oxygen from the air, and becomes fully oxygenated.

As phoſphorus has a ſufficient affinity for oxygen to attract it from the nitric and muriatic acids, we may form phoſphoric acid, by means of theſe acids, in a very ſimple and cheap manner. Fill a tubulated receiver, half full of concentrated nitric acid, and heat it gently, then throw in ſmall pieces of phoſphorus through the tube, theſe are diſſolved with effervеſcence and red fumes of nitrous gas fly off; add phoſphorus ſo long as it will diſſolve, and then increaſe the fire under the retort to drive off the laſt particles of nitric acid; phoſphoric acid, partly fluid and partly concrete, remains in the retort.

TABLE *of the Combinations of Carbonic Acid, with the Saliſiable Baſes, in the Order of Affinity.*

	Reſulting Neutral Salts.	
Names of Baſes.	*New Nomenclature.*	*Old Nomenclature.*
Barytes	Carbonats of * barytes	Aërated or effervefcent heavy earth.
Lime	lime	Chalk, calcareous ſpar, Aërated calcareous earth.
Potaſh	potaſh	Effervefcing or aërated fixed vegetable alkali, mephitis of potaſh.
Soda	ſoda	Aërated or effervefcing fixed mineral alkali, mephitic ſoda.
Magneſia	magneſia	Aërated, effervefcing, mild, or mephitic magneſia.
Ammoniac	ammoniac	Aërated, effervefcing, mild, or mephitic volatile alkali.
Argill	argill	Aërated or effervefcing argillaceous earth, or earth of alum.
Oxyds of zinc	zinc	Zinc ſpar, mephitic or aërated zinc.
iron	iron	Sparry iron-ore, mephitic or aërated iron.
mangaueſe	manganeſe	Aërated manganeſe.
cobalt	cobalt	Aërated cobalt.
nickel	nickel	Aërated nickel.
lead	lead	Sparry lead-ore, or aërated lead.
tin	tin	Aërated tin.
copper	copper	Aërated copper.
biſmuth	biſmuth	Aërated biſmuth.
antimony	antimony	Aërated antimony.
arſenic	arſenic	Aërated arſenic.
mercury	mercury	Aërated mercury.
ſilver	ſilver	Aërated ſilver.
gold	gold	Aërated gold.
platina	platina	Aërated platina.

* As theſe ſalts have only been underſtood of late, they have not, properly ſpeaking, any old names. Mr Morveau, in the Firſt Volume of the Encyclopedia, calls them *Mephites*; Mr Bergman gives them the name of *aërated*; and Mr de Fourcroy, who calls the carbonic acid *chalky acid*, gives them the name of *chalks*.—A.

SECT. XVII.—*Obſervations upon Carbonic Acid, and its Combinations.*

Of all the known acids, the carbonic is the moſt abundant in nature; it exiſts ready formed in chalk, marble, and all the calcareous ſtones, in which it is neuturalized by a particular earth called *lime*. To diſengage it from this combination, nothing more is requiſite than to add ſome ſulphuric acid, or any other which has a ſtronger affinity for lime; a briſk efferveſcence enſues, which is produced by the diſengagement of the carbonic acid which aſſumes the ſtate of gas immediately upon being ſet free. This gas, incapable of being condenſed into the ſolid or liquid form by any degree of cold or of preſſure hitherto known, unites to about its own bulk of water, and thereby forms a very weak acid. It may likewiſe be obtained in great abundance from ſaccharine matter in fermentation, but is then contaminated by a ſmall portion of alkohol which it holds in ſolution.

As charcoal is the radical of this acid, we may form it artificially, by burning charcoal in oxygen gas, or by combining charcoal and metallic oxyds in proper proportions; the oxygen of the oxyd combines with the charcoal, forming

ing carbonic acid gas, and the metal being left free, recovers its metallic or reguline form.

We are indebted for our firſt knowledge of this acid to Dr Black, before whoſe time its property of remaining always in the ſtate of gas had made it to elude the reſearches of chemiſtry.

It would be a moſt valuable diſcovery to ſociety, if we could decompoſe this gas by any cheap proceſs, as by that means we might obtain, for economical purpoſes, the immenſe ſtore of charcoal contained in calcareous earths, marbles, limeſtones, &c. This cannot be effected by ſingle affinity, becauſe, to decompoſe the carbonic acid, it requires a ſubſtance as combuſtible as charcoal itſelf, ſo that we ſhould only make an exchange of one combuſtible body for another not more valuable; but it may poſſibly be accompliſhed by double affinity, ſince this proceſs is ſo readily performed by Nature, during vegetation, from the moſt common materials.

TABLE *of the Combinations of Muriatic Acid, with the Saliſiable Baſes, in the Order of Affinity.*

Names of the baſes.	*Reſulting Neutral Salts.* *New nomenclature.*	*Old nomenclature.*
Barytes.	Muriat of barytes	Sea-ſalt, having baſe of heavy earth.
Potaſh	potaſh	Febrifuge ſalt of Sylvius. Muriated vegetable fixed alkali.
Soda	ſoda	Sea-ſalt.
Lime	lime	Muriated lime. Oil of lime.
Magneſia	magneſia	Marine Epſom ſalt. Muriated magneſia.
Ammoniac	ammoniac	Sal ammoniac.
Argill	argill	Muriated alum, ſea-ſalt with baſe of earth of alum.
Oxyd of zinc	zinc	Sea-ſalt of, or muriatic zinc.
iron	iron	Salt of iron, Martial ſea-ſalt.
manganeſe	manganeſe	Sea-ſalt of manganeſe.
cobalt	cobalt	Sea-ſalt of cobalt.
nickel	nickel	Sea-ſalt of nickel.
lead	lead	Horny-lead. Plumbum corneum.
tin	ſmoaking of tin	Smoaking liquor of Libavius.
	ſolid of tin	Solid butter of tin.
copper	copper	Sea-ſalt of copper.
biſmuth	biſmuth	Sea-ſalt of biſmuth.
antimony	antimony	Sea-ſalt of antimony.
arſenic	arſenic	Sea-ſalt of arſenic.
mercury	ſweet of mercury	Sweet ſublimate of mercury, calomel, aquila alba.
	corroſive of mercury	Corroſive ſublimate of mercury.
ſilver	ſilver	Horny ſilver, argentum corneum, luna cornea.
gold	gold	Sea-ſalt of gold.
platina	platina	Sea-ſalt of platina.

TABLE

Table *Of the Combinations of Oxygenated Muriatic Acid, with the Salifiable Baſes, in the Order of Affinity.*

Names of the Baſes.	*Names of the Neutral Salts by the new Nomenclature.*
	Oxygenated muriat of
Barytes	barytes.
Potaſh	potaſh.
Soda	ſoda.
Lime	lime.
Magneſia	magneſia.
Argill	argill.
Oxyd of	
zinc	zinc.
iron	iron.
manganeſe	manganeſe.
cobalt	cobalt.
nickel	nickel.
lead	lead.
tin	tin.
copper	copper.
biſmuth	biſmuth.
antimony	antimony.
arſenic	arſenic.
mercury	mercury.
ſilver	ſilver.
gold	gold.
platina	platina.

This order of ſalts, entirely unknown to the ancient chemiſts, was diſcovered in 1786 by Mr Berthollet. —A.

Sect.

SECT. XIX.—*Obſervations upon Muriatic and Oxygenated Muriatic Acids, and their Combinations.*

Muriatic acid is very abundant in the mineral kingdom naturally combined with different ſalifiable baſes, eſpecially with ſoda, lime, and magneſia. In ſea-water, and the water of ſeveral lakes, it is combined with theſe three baſes, and in mines of rock-ſalt it is chiefly united to ſoda. This acid does not appear to have been hitherto decompoſed in any chemical experiment; ſo that we have no idea whatever of the nature of its radical, and only conclude, from analogy with the other acids, that it contains oxygen as its acidifying principle. Mr Berthollet ſuſpects the radical to be of a metallic nature; but, as Nature appears to form this acid daily, in inhabited places, by combining miaſmata with aëriform fluids, this muſt neceſſarily ſuppoſe a metallic gas to exiſt in the atmoſphere, which is certainly not impoſſible, but cannot be admitted without proof.

The muriatic acid has only a moderate adherence to the ſalifiable baſes, and can readily be driven from its combination with theſe by ſulphuric acid. Other acids, as the nitric, for inſtance, may anſwer the ſame purpoſe; but nitric acid being volatile, would mix, during diſtillation, with the muriatic. About one part of ſulphuric acid is ſufficient to decompoſe two parts of decrepitated ſea-ſalt. This operation is performed in a tubulated retort, having Woulfe's apparatus, (Pl. IV. Fig. 1.), adapted to it. When all the junctures are properly luted, the ſea-ſalt is put into the retort through the tube, the ſulphuric acid is poured on, and the opening immediately cloſed with its ground cryſtal ſtopper. As the muriatic acid can only ſubſiſt in the gaſſeous form in the ordinary temperature, we could not condenſe it without the preſence of water. Hence the uſe of the water with which the bottles in Woulfe's apparatus are half filled; the muriatic acid gas, driven off from the ſea-ſalt in the retort, combines with the water, and forms what the old chemiſts called *ſmoaking ſpirit of ſalt*, or *Glauber's ſpirit of ſea-ſalt*, which we now name *muriatic acid*.

The acid obtained by the above proceſs is ſtill capable of combining with a farther doſe of oxygen, by being diſtilled from the oxyds of manganeſe, lead, or mercury, and the reſulting acid, which we name *oxygenated muriatic acid*, can only, like the former, exiſt in the gaſſeous form, and is abſorbed, in a much ſmaller quantity by water. When the impregnation of water with this gas is puſhed beyond a certain point, the ſuperabundant acid precipitates to the bottom of the veſſels in a concrete form. Mr Berthollet has ſhown

ſhown that this acid is capable of combining with a great number of the ſalifiable baſes; the neutral ſalts which reſult from this union are ſuſceptible of deflagrating with charcoal, and many of the metallic ſubſtances; theſe deflagrations are very violent and dangerous, owing to the great quantity of caloric which the oxygen carries alongſt with it into the compoſition of oxygenated muriatic acid.

TABLE *of the Combinations of Nitro-muriatic Acid with the Salifiable Baſes, in the Order of Affinity, ſo far as is known.*

Names of the Baſes.	*Names of the Neutral Salts.*
Argill	Nitro-muriat of argill.
Ammoniac	ammoniac.
Oxyd of	
antimony	antimony.
ſilver	ſilver.
arſenic	arſenic.
Barytes	barytes.
Oxyd of	
biſmuth	biſmuth.
Lime	lime.
Oxyd of	
cobalt	cobalt.
copper	copper.
tin	tin.
iron	iron.
Magneſia	magneſia.
Oxyd of	
mangaueſe	mangaueſe.
mercury	mercury.
molybdena	molybdena
nickel	nickel.
gold	gold.
platina	platina.
lead	lead
Potaſh	potaſh.
Soda	ſoda.
Oxyd of	
tungſtein	tungſtein.
zinc	zinc.

Note.—Moſt of theſe combinations, eſpecially thoſe with the earths and alkalies, have been little examined, and we are yet to learn whether they form a mixed ſalt in which the compound radical remains combined, or if the two acids ſeparate, to form two diſtinct neutral ſalts.—A.

SECT. XX.—*Obſervations upon the Nitro-Muriatic Acid, and its Combinations.*

The nitro-muriatic acid, formerly called *aqua regia*, is formed by a mixture of nitric and muriatic acids; the radicals of theſe two acids combine together, and form a compound baſe, from which an acid is produced, having properties peculiar to itſelf, and diſtinct from thoſe of all other acids, eſpecially the property of diſſolving gold and platina.

In diſſolutions of metals in this acid, as in all other acids, the metals are firſt oxydated by attracting a part of the oxygen from the compound radical. This occaſions a diſengagement of a particular ſpecies of gas not hitherto deſcribed, which may be called *nitro-muriatic gas;* it has a very diſagreeable ſmell, and is fatal to animal life when reſpired; it attacks iron, and cauſes it to ruſt; it is abſorbed in conſiderable quantity by water, which thereby acquires ſome ſlight characters of acidity. I had occaſion to make theſe remarks during a courſe of experiments upon platina, in which I diſſolved a conſiderable quantity of that metal in nitro-muriatic acid.

I at firſt ſuſpected that, in the mixture of nitric and muriatic acids, the latter attracted a part of the oxygen from the former, and became converted into oxygenated muriatic acid, which gave it the property of diſſolving gold; but ſeveral facts remain inexplicable upon this ſuppoſition. Were it ſo, we muſt be able to diſengage nitrous gas by heating this acid, which however does not ſenſibly happen. From theſe conſiderations, I am led to adopt the opinion of Mr Berthollet, and to conſider nitro-muriatic acid as a ſingle acid, with a compound baſe or radical.

TABLE *of the Combinations of Fluoric Acid, with the Salifiable Baſes, in the Order of Affinity.*

Names of the Baſes.	*Names of the Neutral Salts.*
Lime	Fluat of lime.
Barytes	barytes.
Magneſia	magneſia.
Potaſh	potaſh.
Soda	ſoda.
Ammoniac	ammoniac.
Oxyd of	
zinc	zinc.
manganeſe	manganeſe.
iron	iron.
lead	lead.
tin	tin.
cobalt	cobalt.
copper	copper.
nickel	nickel.
arſenic	arſenic.
biſmuth	biſmuth.
mercury	mercury.
ſilver	ſilver.
gold	gold.
platina	platina.
And by the dry way,	
Argill	Fluat of argill.

Note.—Theſe combinations were entirely unknown to the old chemiſts, and conſequently have no names in the old nomenclature.—A.

SECT.

Sect. XXI.—*Obſervations upon the Fluoric Acid, and its Combinations.*

Fluoric exiſts ready formed by Nature in the fluoric ſpars *, combined with calcareous earth, ſo as to form an inſoluble neutral ſalt. To obtain it diſengaged from that combination, fluor ſpar, or fluat of lime, is put into a leaden retort, with a proper quantity of ſulphuric acid, a recipient likewiſe of lead, half full of water, is adapted, and fire is applied to the retort. The ſulphuric acid, from its greater affinity, expels the fluoric acid which paſſes over and is abſorbed by the water in the receiver. As fluoric acid is naturally in the gaſſeous form in the ordinary temperature, we can receive it in a pneumato-chemical apparatus over mercury. We are obliged to employ metallic veſſels in this proceſs, becauſe fluoric acid diſſolves glaſs and ſilicious earth, and even renders theſe bodies volatile, carrying them over with itſelf in diſtillation in the gaſſeous form.

We are indebted to Mr Margraff for our firſt acquaintance with this acid, though, as he could never procure it free from combination with a conſiderable quantity of ſilicious earth, he was ignorant

---

* Commonly called *Derbyſhire ſpars.*—E.

ignorant of its being an acid ſui generis. The Duke de Liancourt, under the name of Mr Boulanger, conſiderably increaſed our knowledge of its properties; and Mr Scheele ſeems to have exhauſted the ſubject. The only thing remaining is to endeavour to diſcover the nature of the fluoric radical, of which we cannot hitherto form any ideas, as the acid does not appear to have been decompoſed in any experiment. It is only by means of compound affinity that experiments ought to be made with this view, with any probability of ſucceſs.

Table *of the Combinations of Boracic Acid, with the Saliſiable Baſes, in the Order of Affinity.*

Baſes.	*Neutral Salts.*
Lime	Borat of lime.
Barytes	barytes.
Magneſia	magneſia.
Potaſh	potaſh.
Soda	ſoda.
Ammoniac	ammoniac.
Oxyd of	
zinc	zinc.
iron	iron.
lead	lead.
tin	tin.
cobalt	cobalt.
copper	copper.
nickel	nickel.
mercury	mercury.
Argill	argill.

Note.—Moſt of theſe combinations were neither known nor named by the old chemiſts. The boracic acid was formerly called *ſedative ſalt*, and its compounds *borax*, with baſe of fixed vegetable alkali, &c.—A.

SECT. XXII.—*Obſervations upon Boracic Acid and its Combinations.*

This is a concrete acid, extracted from a ſalt procured from India called *borax* or *tincall.* Although borax has been very long employed in the arts, we have as yet very imperfect knowledge of its origin, and of the methods by which it is extracted and purified; there is reaſon to believe it to be a native ſalt, found in the earth in certain parts of the eaſt, and in the water of ſome lakes. The whole trade of borax is in the hands of the Dutch, who have been excluſively poſſeſſed of the art of purifying it till very lately, that Meſſrs L'Eguillier of Paris have rivalled them in the manufacture; but the proceſs ſtill remains a ſecret to the world.

By chemical analyſis we learn that borax is a neutral ſalt with exceſs of baſe, conſiſting of ſoda, partly ſaturated with a peculiar acid long called *Homberg's ſedative ſalt*, now *the boracic acid.* This acid is found in an uncombined ſtate in the waters of certain lakes. That of Cherchiais in Italy contains 94½ grains in each pint of water.

To obtain boracic acid, diſſolve ſome borax in boiling water, filtrate the ſolution, and add ſulphuric acid, or any other having greater affinity

nity to ſoda than the boracic acid; this latter acid is ſeparated, and is procured in a cryſtalline form by cooling. This acid was long conſidered as being formed during the proceſs by which it is obtained, and was conſequently ſuppoſed to differ according to the nature of the acid employed in ſeparating it from the ſoda; but it is now univerſally acknowledged that it is identically the ſame acid, in whatever way procured, provided it be properly purified from mixture of other acids, by waſhing, and by repeated ſolution and criſtallization. It is ſoluble both in water and alkohol, and has the property of communicating a green colour to the flame of that ſpirit. This circumſtance led to a ſuſpicion of its containing copper, which is not confirmed by any deciſive experiment. On the contrary, if it contain any of that metal, it muſt only be conſidered as an accidental mixture. It combines with the ſalifiable baſes in the humid way; and though, in this manner, it is incapable of diſſolving any of the metals directly, this combination is readily affected by compound affinity.

The Table preſents its combinations in the order of affinity in the humid way; but there is a conſiderable change in the order when we operate via ſicca; for, in that caſe, argill, though the laſt in our liſt, muſt be placed immediately after ſoda.

The boracic radical is hitherto unknown; no experiments having as yet been able to decompoſe the acid; we conclude, from analogy with the other acids, that oxygen exiſts in its compoſition as the acidifying principle.

TABLE *of the Combinations of Arſeniac Acid, with the Salifiable Baſes, in the Order of Affinity.*

Baſes.	*Neutral Salts.*
Lime	Arſeniat of lime.
Barytes	barytes.
Magneſia	magneſia.
Potaſh	potaſh.
Soda	ſoda.
Ammoniac	ammoniac.
Oxyd of	
zinc	zinc.
manganeſe	manganeſe.
iron	iron.
lead	lead.
tin	tin.
cobalt	cobalt.
copper	copper.
nickel	nickel.
biſmuth	biſmuth.
mercury	mercury.
antimony	antimony.
ſilver	ſilver.
gold	gold.
platina	platina.
Argill	argill.

Note.—This order of ſalts was entirely unknown to the antient chemiſts. Mr Macquer, in 1746, diſcovered the combinations of arſeniac acid with potaſh and ſoda, to which he gave the name of *arſenical neutral ſalts*.—A.

SECT. XXIII.—*Obſervations upon Arſeniac Acid, and its Combinations.*

In the Collections of the Academy for 1746, Mr Macquer ſhows that, when a mixture of white oxyd of arſenic and nitre are ſubjected to the action of a ſtrong fire, a neutral ſalt is obtained, which he calls *neutral ſalt of arſenic.* At that time, the cauſe of this ſingular phenomenon, in which a metal acts the part of an acid, was quite unknown; but more modern experiments teach that, during this proceſs, the arſenic becomes oxygenated, by carrying off the oxygen of the nitric acid; it is thus converted into a real acid, and combines with the potaſh. There are other methods now known for oxygenating arſenic, and obtaining its acid free from combination. The moſt ſimple and moſt effectual of theſe is as follows: Diſſolve white oxyd of arſenic in three parts, by weight, of muriatic acid; to this ſolution, in a boiling ſtate, add two parts of nitric acid, and evaporate to dryneſs. In this proceſs the nitric acid is decompoſed, its oxygen unites with the oxyd of arſenic, and converts it into an acid, and the nitrous radical flies off in the ſtate of nitrous gas; whilſt the muriatic acid is converted by the heat into muriatic acid gas, and may be collected in proper veſſels. The arſeniac acid is entirely freed from the other acids employed during the proceſs by heating it in a crucible till it begins to grow red; what remains is pure concrete arſeniac acid.

Mr Scheele's proceſs, which was repeated with great ſucceſs by Mr Morveau, in the laboratory at Dijon, is as follows: Diſtil muriatic acid from the black oxyd of manganeſe, this converts it into oxygenated muriatic acid, by carrying off the oxygen from the manganeſe, receive this in a recipient containing white oxyd of arſenic, covered by a little diſtilled water; the arſenic decompoſes the oxygenated muriatic acid, by carrying off its ſuperſaturation of oxygen, the arſenic is converted into arſeniac acid, and the oxygenated muriatic acid is brought back to the ſtate of common muriatic acid. The two acids are ſeparated by diſtillation, with a gentle heat increaſed towards the end of the operation, the muriatic acid paſſes over, and the arſeniac acid remains behind in a white concrete form.

The arſeniac acid is conſiderably leſs volatile than white oxyd of arſenic; it often contains white oxyd of arſenic in ſolution, owing to its not being ſufficiently oxygenated; this is prevented by continuing to add nitrous acid, as in the former proceſs, till no more nitrous gas is produced. From all theſe obſervations I would give the following definition of arſeniac

arſeniac acid. It is a white concrete metallic acid, formed by the combination of arſenic with oxygen, fixed in a red heat, ſoluble in water, and capable of combining with many of the ſalifiable baſes.

SECT. XXIV.—*Obſervations upon Molybdic Acid, and its Combinations with Acidifiable Baſes* *.

Molybdena is a particular metallic body, capable of being oxygenated, ſo far as to become a true concrete acid †. For this purpoſe, one part ore of molybdena, which is a natural ſulphuret of that metal, is put into a retort, with five or ſix parts nitric acid, diluted with a quarter of its weight of water, and heat is applied to the retort; the oxygen of the nitric acid acts both upon the molybdena and the ſulphur, converting the one into molybdic, and the other into ſulphuric acid; pour on freſh quantities of nitric acid ſo long as any red fumes of nitrous gas

---

[*] I have not added the Table of theſe combinations, as the order of their affinity is entirely unknown; they are called *molybdats of argil, antimony, potaſh*, &c.—E.

[†] This acid was diſcovered by Mr Scheele, to whom chemiſtry is indebted for the diſcovery of ſeveral other acids.—A.

gas eſcape; the molydbena is then oxygenated as far as is poſſible, and is found at the bottom of the retort in a pulverulent form, reſembling chalk. It muſt be waſhed in warm water, to ſeparate any adhering particles of ſulphuric acid; and, as it is hardly ſoluble, we loſe very little of it in this operation. All its combinations with ſalifiable baſes were unknown to the ancient chemiſts.

TABLE *of the Combinations of Tungſtic Acid with the Salifiable Baſes.*

Baſes.	*Neutral Salts.*
Lime	Tungſtat of lime.
Barytes	barytes.
Magneſia	magneſia.
Potaſh	potaſh.
Soda	ſoda.
Ammoniac	ammoniac.
Argill	argill.
Oxyd of antimony *, &c.	antimony †, &c.

SECT. XXV.—*Obſervations upon Tungſtic Acid, and its Combinations.*

Tungſtein is a particular metal, the ore of which has frequently been confounded with that of tin. The ſpecific gravity of this ore is to water as 6 to 1; in its form of criſtallization it reſembles

---

* The combinations with metallic oxyds were ſet down by Mr Lavoiſier in alphabetical order; their order of affinity being unknown, I have omitted them, as ſerving no purpoſe.—E.

† All theſe ſalts were unknown to the ancient chemiſts.—A.

ſembles the garnet, and varies in colour from a pearl-white to yellow and reddiſh; it is found in ſeveral parts of Saxony and Bohemia. The mineral called *Wolfram*, which is frequent in the mines of Cornwal, is likewiſe an ore of this metal. In all theſe ores the metal is oxydated; and, in ſome of them, it appears even to be oxygenated to the ſtate of acid, being combined with lime into a true tungſtat of lime.

To obtain the acid free, mix one part of ore of tungſtein with four parts of carbonat of potaſh, and melt the mixture in a crucible, then powder and pour on twelve parts of boiling water, add nitric acid, and the tungſtic acid precipitates in a concrete form. Afterwards, to inſure the complete oxygenation of the metal, add more nitric acid, and evaporate to dryneſs, repeating this operation ſo long as red fumes of nitrous gas are produced. To procure tungſtic acid perfectly pure, the fuſion of the ore with carbonat of potaſh muſt be made in a crucible of platina, otherwiſe the earth of the common crucibles will mix with the products, and adulterate the acid.

TABLE *of the Combinations of Tartarous Acid, with the Salifiable Baſes, in the Order of Affinity.*

Baſes,	*Neutral Salts.*
Lime	Tartarite of lime.
Barytes	barytes.
Magneſia	magneſia.
Potaſh	potaſh.
Soda	ſoda.
Ammoniac	ammoniac.
Argill	argill.
Oxyd of	
zinc	zinc.
iron	iron.
manganeſe	manganeſe.
cobalt	cobalt.
nickel	nickel.
lead	lead.
tin	tin.
copper	copper.
biſmuth	biſmuth.
antimony	antimony.
arſenic	arſenic.
ſilver	ſilver.
mercury	mercury.
gold	gold.
platina	platina.

Sect. XXVI.—*Obſervations upon Tartarous Acid, and its Combinations.*

Tartar, or the concretion which fixes to the inſide of veſſels in which the fermentation of wine is completed, is a well known ſalt, compoſed of a peculiar acid, united in conſiderable exceſs to potaſh. Mr Scheele firſt pointed out the method of obtaining this acid pure. Having obſerved that it has a greater affinity to lime than to potaſh, he directs us to proceed in the following manner. Diſſolve purified tartar in boiling water, and add a ſufficient quantity of lime till the acid be completely ſaturated. The tartarite of lime which is formed, being almoſt inſoluble in cold water, falls to the bottom, and is ſeparated from the ſolution of potaſh by decantation; it is afterwards waſhed in cold water, and dried; then pour on ſome ſulphuric acid, diluted with eight or nine parts of water, digeſt for twelve hours in a gentle heat, frequently ſtirring the mixture; the ſulphuric acid combines with the lime, and the tartarous acid is left free. A ſmall quantity of gas, not hitherto examined, is diſengaged during this proceſs. At the end of twelve hours, having decanted off the clear liquor, waſh the ſulphat of lime in cold water, which add to the decanted liquor,

liquor, then evaporate the whole, and the tartarous acid is obtained in a concrete form. Two pounds of purified tartar, by means of from eight to ten ounces of ſulphuric acid, yield about eleven ounces of tartarous acid.

As the combuſtible radical exiſts in exceſs, or as the acid from tartar is not fully ſaturated with oxygen, we call it *tartarous acid*, and the neutral ſalts formed by its combinations with ſalifiable baſes *tartarites*. The baſe of the tartarous acid is a carbono-hydrous or hydro-carbonous radical, leſs oxygenated than in the oxalic acid; and it would appear, from the experiments of Mr Haſſenfratz, that azote enters into the compoſition of the tartarous radical, even in conſiderable quantity. By oxygenating the tartarous acid, it is convertible into oxalic, malic, and acetous acids; but it is probable the proportions of hydrogen and charcoal in the radical are changed during theſe converſions, and that the difference between theſe acids does not alone conſiſt in the different degrees of oxygenation.

The tartarous acid is ſuſceptible of two degrees of ſaturation in its combinations with the fixed alkalies; by one of theſe a ſalt is formed with exceſs of acid, improperly called *cream of tartar*, which in our new nomenclature is named *acidulous tartarite of potaſh*; by a ſecond or equal degree of ſaturation a perfectly neutral ſalt is formed, formerly called *vegetable ſalt*, which

which we name *tartarite of potaſh*. With ſoda this acid forms tartarite of ſoda, formerly called *ſal de Seignette*, or *ſal polychreſt of Rochell.*

SECT. XXVII.—*Obſervations upon Malic Acid, and its Combinations with the Saliſiable Baſes* *.

The malic acid exiſts ready formed in the ſour juice of ripe and unripe apples, and many other fruits, and is obtained as follows: Saturate the juice of apples with potaſh or ſoda, and add a proper proportion of acetite of lead diſſolved in water; a double decompoſition takes place, the malic acid combines with the oxyd of lead and precipitates, being almoſt inſoluble, and the acetite of potaſh or ſoda remains in the liquor. The malat of lead being ſeparated by decantation, is waſhed with cold water, and ſome dilute ſulphuric acid is added; this unites with the lead into an inſoluble ſulphat, and the malic acid remains free in the liquor.

This acid, which is found mixed with citric and tartarous acid in a great number of fruits, is a kind of medium between oxalic and acetous

---

* I have omitted the Table, as the order of affinity is unknown, and is given by Mr Lavoiſier only in alphabetical order. All the combinations of malic acid with ſaliſiable baſes, which are named *malats*, were unknown to the ancient chemiſts.—E.

tous acids being more oxygenated than the former, and leſs ſo than the latter. From this circumſtance, Mr Hermbſtadt calls it *imperfect vinegar ;* but it differs likewiſe from acetous acid, by having rather more charcoal, and leſs hydrogen, in the compoſition of its radical.

When an acid much diluted has been uſed in the foregoing proceſs, the liquor contains oxalic as well as malic acid, and probably a little tartarous, theſe are ſeparated by mixing lime-water with the acids, oxalat, tartarite, and malat of lime are produced ; the two former, being inſoluble, are precipitated, and the malat of lime remains diſſolved ; from this the pure malic acid is ſeparated by the acetite of lead, and afterwards by ſulphuric acid, as directed above.

TABLE *of the Combinations of Citric Acid, with the Salifiable Baſes, in the Order of Affinity* *.

Baſes.	*Neutral Salts.*
Barytes	Citrat of barytes.
Lime	lime.
Magneſia	magneſia.
Potaſh	potaſh.
Soda	ſoda.
Ammoniac	ammoniac.
Oxyd of	
zinc	zinc.
manganeſe	manganeſe.
iron	iron.
lead	lead.
cobalt	cobalt.
copper	copper.
arſenic	arſenic.
mercury	mercury.
antimony	antimony.
ſilver	ſilver.
gold	gold.
platina	platina.
Argill	argill.

---

* Theſe combinations were unknown to the ancient chemiſts. The order of affinity of the ſalifiable baſes with this acid was determined by Mr Bergman and by Mr de Breney of the Dijon Academy.—A.

SECT.

SECT. XXVIII.—*Obſervations upon Citric Acid, and its Combinations.*

The citric acid is procured by expreſſion from lemons, and is found in the juices of many other fruits mixed with malic acid. To obtain it pure and concentrated, it is firſt allowed to depurate from the mucous part of the fruit by long reſt in a cool cellar, and is afterwards concentrated by expoſing it to the temperature of 4 or 5 degrees below Zero, from 21° to 23° of Fahrenheit, the water is frozen, and the acid remains liquid, reduced to about an eighth part of its original bulk. A lower degree of cold would occaſion the acid to be engaged amongſt the ice, and render it difficultly ſeparable. This proceſs was pointed out by Mr Georgius.

It is more eaſily obtained by ſaturating the lemon-juice with lime, ſo as to form a citrat of lime, which is inſoluble in water; waſh this ſalt, and pour on a proper quantity of ſulphuric acid; this forms a ſulphat of lime, which precipitates and leaves the citric acid free in the liquor.

TABLE *of the Combinations of Pyro-lignous Acid with the Salifiable Baſes, in the Order of Affinity* *.

Baſes.	*Neutral Salts.*
Lime	Pyro-mucite of lime.
Barytes	barytes.
Potaſh	potaſh.
Soda	ſoda.
Magneſia	magneſia.
Ammoniac	ammoniac.
Oxyd of	
zinc	zinc.
mangaueſe	manganeſe.
iron	iron.
lead	lead
tin	tin.
cobalt	cobalt.
copper	copper.
nickel	nickel.
arſenic	arſenic.
biſmuth	biſmuth.
mercury	mercury.
antimony	antimony.
ſilver	ſilver.
gold	gold.
platina	platina.
Argill	argill.

---

* The above affinities were determined by Meſſrs de Morveau and Eloi Bourſier de Clervaux. Theſe combinations were entirely unknown till lately.—A.

Sect. XXIX.—*Obſervations upon Pyro-lignous Acid, and its Combinations.*

The ancient chemiſts obſerved that moſt of the woods, eſpecially the more heavy and compact ones, gave out a particular acid ſpirit, by diſtillation, in a naked fire; but, before Mr Goetling, who gives an account of his experiments upon this ſubject in Crell's Chemical Journal for 1779, no one had ever made any inquiry into its nature and properties. This acid appears to be the ſame, whatever be the wood it is procured from. When firſt diſtilled, it is of a brown colour, and conſiderably impregnated with charcoal and oil; it is purified from theſe by a ſecond diſtillation. The pyro-lignous radical is chiefly compoſed of hydrogen and charcoal.

Sect. XXX.—*Obſervations upon Pyro-tartarous Acid, and its Combinations with the Salifiable Baſes* *.

The name of *Pyro-tartarous acid* is given to a dilute empyreumatic acid obtained from purified

---

* The order of affinity of the ſalifiable baſes with this acid is hitherto unknown. Mr Lavoiſier, from its ſimila-

fied acidulous tartarite of potaſh by diſtillation in a naked fire. To obtain it, let a retort be half filled with powdered tartar, adapt a tubulated recipient, having a bent tube communicating with a bell-glaſs in a pneumato-chemical apparatus; by gradually raiſing the fire under the retort, we obtain the pyro-tartarous acid mixed with oil, which is ſeparated by means of a funnel. A vaſt quantity of carbonic acid gas is diſengaged during the diſtillation. The acid obtained by the above proceſs is much contaminated with oil, which ought to be ſeparated from it. Some authors adviſe to do this by a ſecond diſtillation; but the Dijon academicians inform us, that this is attended with great danger from exploſions which take place during the proceſs.

ſimilarity to pyro-lignous acid, ſuppoſes the order to be the ſame in both; but, as this is not aſcertained by experiment, the table is omitted. All theſe combinations, called *Pyro-tartarites*, were unknown till lately.—E.

TABLE *of the Combinations of Pyro-mucous Acid, with the Salifiable Baſes, in the Order of Affinity* *.

Baſes.	*Neutral Salts.*
Potaſh	Pyro-mucite of potaſh.
Soda	ſoda.
Barytes	barytes.
Lime	lime.
Magneſia	magneſia.
Ammoniac	ammoniac.
Argill	argill.
Oxyd of	
zinc	zinc.
manganeſe	manganeſe.
iron	iron.
lead	lead.
tin	tin.
cobalt	cobalt.
copper	copper.
nickel	nickel.
arſenic	arſenic.
biſmuth	biſmuth.
antimony	antimony.

---

* All theſe combinations were unknown to the ancient chemiſts.—A.

Sect. XXXI.—*Obſervations upon Pyro-mucous Acid, and its Combinations.*

This acid is obtained by diſtillation in a naked fire from ſugar, and all the ſaccharine bodies; and, as theſe ſubſtances ſwell greatly in the fire, it is neceſſary to leave ſeven-eighths of the retort empty. It is of a yellow colour, verging to red, and leaves a mark upon the ſkin, which will not remove but alongſt with the epidermis. It may be procured leſs coloured, by means of a ſecond diſtillation, and is concentrated by freezing, as is directed for the citric acid. It is chiefly compoſed of water and oil ſlightly oxygenated, and is convertible into oxalic and malic acids by farther oxygenation with the nitric acid.

It has been pretended that a large quantity of gas is diſengaged during the diſtillation of this acid, which is not the caſe if it be conducted ſlowly, by means of moderate heat.

TABLE *of the Combinations of the Oxalic Acid, with the Salifiable Baſes, in the Order of Affinity* *.

Baſes.	*Neutral Salts.*
Lime	Oxalat of lime.
Barytes	barytes.
Magneſia	magneſia.
Potaſh	potaſh.
Soda	ſoda.
Ammoniac	ammoniac.
Argill	argill.
Oxyd of	
zinc	zinc.
iron	iron.
manganeſe	manganeſe.
cobalt	cobalt.
nickel	nickel.
lead	lead.
copper	copper.
biſmuth	biſmuth.
antimony	antimony.
arſenic	arſenic.
mercury	mercury.
ſilver	ſilver.
gold	gold.
platina	platina.

---

* All unknown to the ancient chemiſts.—A.

SECT.

SECT. XXXII.—*Obſervations upon Oxalic Acid, and its Combinations.*

The oxalic acid is moſtly prepared in Switzerland and Germany from the expreſſed juice of ſorrel, from which it criſtallizes by being left long at reſt; in this ſtate it is partly ſaturated with potaſh, forming a true acidulous oxalat of potaſh, or ſalt with exceſs of acid. To obtain it pure, it muſt be formed artificially by oxygenating ſugar, which ſeems to be the true oxalic radical. Upon one part of ſugar pour ſix or eight parts of nitric acid, and apply a gentle heat; a conſiderable effervefcence takes place, and a great quantity of nitrous gas is diſengaged; the nitric acid is decompoſed, and its oxygen unites to the ſugar: By allowing the liquor to ſtand at reſt, criſtals of pure oxalic acid are formed, which muſt be dried upon blotting paper, to ſeparate any remaining portions of nitric acid; and, to enſure the purity of the acid, diſſolve the criſtals in diſtilled water, and criſtallize them afreſh.

From the liquor remaining after the firſt criſtallization of the oxalic acid we may obtain malic acid by refrigeration: This acid is more oxygenated than the oxalic; and, by a further oxygenation,

To face Page 267.

TABLE of the Combinations of Acetous Acid with the Saliſiable Baſes in the Order of Affinity.

Baſes.	*Neutral ſalts.*	*Names of the reſulting neutral ſalts according to the old nomenclature.*
Barytes	Acetite of barytes . .	Unknown to the ancients. Diſcovered by Mr de Morveau, who calls it *barotic acéte.*
Potaſh	——— potaſh . .	Secret terra foliata tartari of Muller. Arcanum tartari of Baſil Valentin and Paracelſus Purgative magiſtery of tartar of Schroëder. Eſſential ſalt of wine of Zwelfer. Regener ted tartar of Tachenius. Diuretic ſalt of Sylvius and Wilſon.
Soda	——— ſoda . .	Foliated earth with baſe of mineral alkali. Mineral or cryſtalliſable foliated earth. Miner acetous ſalt.
Lime	——— lime . .	Salt of chalk, coral, or crabs eyes; mentioned by Hartman.
Magneſia . . .	——— magneſia	Firſt mentioned by Mr Wenzel.
Ammoniac . . .	——— ammoniac	Spiritus Mindereri. Ammoniacal acetous ſalt.
Oxyd of zinc . .	——— zinc . . .	Known to Glauber, Schwedemberg, Reſpour, Pott, de Laſſone, and Wenzel, but not nam
——— manganeſe	——— manganeſe	Unknown to the ancients.
——— iron . .	——— iron . .	Martial vinegar. Deſcribed by Monnet, Wenzel, and the Duke d'Ayen.
——— lead . .	——— lead . .	Sugar, vinegar, and ſalt of lead or Saturn.
——— tin . . .	——— tin . .	Known to Lemery, Margraff, Monnet, Weſlendorf, and Wenzel, but not named.
——— cobalt . .	——— cobalt . .	Sympathetic ink of Mr Cadet.
——— copper . .	——— copper . .	Verdigris, cryſtals of verditer, verditer, diſtilled verdigris, cryſtals of Venus or of copper.
——— nickel . .	——— nickel . .	Unknown to the ancients.
——— arſenic . .	——— arſenic . .	Arſenico-acetous fuming liquor, liquid phoſphorus of Mr Cadet.
——— biſmuth . .	——— biſmuth .	Sugar of biſmuth of Mr Geoffroi. Known to Gellert, Pott, Weſlendorf, Bergman, and Morveau.
——— mercury .	——— mercury .	Mercurial foliated earth, Keyſer's famous antivenereal remedy. Mentioned by Gebav 1748; known to Helot, Margraff, Baumé, Bergman, and de Morveau.
——— antimony .	——— antimony	Unknown.
——— ſilver . .	——— ſilver . .	Deſcribed by Margraff, Monnet, and Wenzel; unknown to the ancients.
——— gold . .	——— gold . .	Little known, mentioned by Schroëder and Juncker.
——— platina . .	——— platina . .	Unknown.
Argill	——— argill . .	According to Mr Wenzel, vinegar diſſolves only a very ſmall proportion of argill.

genation, the ſugar is convertible into acetous acid, or vinegar.

The oxalic acid, combined with a ſmall quantity of ſoda or potaſh, has the property, like the tartarous acid, of entering into a number of combinations without ſuffering decompoſition: Theſe combinations form triple ſalts, or neutral ſalts with double baſes, which ought to have proper names. The ſalt of ſorrel, which is potaſh having oxalic acid combined in exceſs, is named acidulous oxalat of potaſh in our new nomenclature.

The acid procured from ſorrel has been known to chemiſts for more than a century, being mentioned by Mr Duclos in the Memoirs of the Academy for 1688, and was pretty accurately deſcribed by Boerhaave; but Mr Scheele firſt ſhowed that it contained potaſh, and demonſtrated its identity with the acid formed by the oxygenation of ſugar.

SECT. XXXIII.—*Obſervations upon Acetous Acid, and its Combinations.*

This acid is compoſed of charcoal and hydrogen united together, and brought to the ſtate of an acid by the addition of oxygen; it is conſequently formed by the ſame elements with the

the tartarous oxalic, citric, malic acids, and others, but the elements exiſt in different proportions in each of theſe; and it would appear that the acetous acid is in a higher ſtate of oxygenation than theſe other acids. I have ſome reaſon to believe that the acetous radical contains a ſmall portion of azote; and, as this element is not contained in the radicals of any vegetable acid except the tartarous, this circumſtance is one of the cauſes of difference. The acetous acid, or vinegar, is produced by expoſing wine to a gentle heat, with the addition of ſome ferment: This is uſually the ley, or mother, which has ſeparated from other vinegar during fermentation, or ſome ſimilar matter. The ſpiritous part of the wine, which conſiſts of charcoal and hydrogen, is oxygenated, and converted into vinegar: This operation can only take place with free acceſs of air, and is always attended by a diminution of the air employed in conſequence of the abſorption of oxygen; wherefore, it ought always to be carried on in veſſels only half filled with the vinous liquor ſubmitted to the acetous fermentation. The acid formed during this proceſs is very volatile, is mixed with a large proportion of water, and with many foreign ſubſtances; and, to obtain it pure, it is diſtilled in ſtone or glaſs veſſels by a gentle fire. The acid which paſſes over in diſtillation is ſomewhat changed by the proceſs, and is not exactly of the ſame nature with what remains in the alembic, but ſeems leſs oxygenated: This circumſtance has not been formerly obſerved by chemiſts.

Diſtillation is not ſufficient for depriving this acid of all its unneceſſary water; and, for this purpoſe, the beſt way is by expoſing it to a degree of cold from 4° to 6° below the freezing point, from 19° to 23° of Fahrenheit; by this means the aqueous part becomes frozen, and leaves the acid in a liquid ſtate, and conſiderably concentrated. In the uſual temperature of the air, this acid can only exiſt in the gaſſeous form, and can only be retained by combination with a large proportion of water. There are other chemical proceſſes for obtaining the acetous acid, which conſiſt in oxygenating the tartarous, oxalic, or malic acids, by means of nitric acid; but there is reaſon to believe the proportions of the elements of the radical are changed during this proceſs. Mr Haſſenfratz is at preſent engaged in repeating the experiments by which theſe converſions are ſaid to be produced.

The combinations of acetous acid with the various ſalifiable baſes are very readily formed; but moſt of the reſulting neutral ſalts are not criſtallizable, whereas thoſe produced by the tartarous and oxalic acids are, in general, hardly ſoluble. Tartarite and oxalat of lime are not

not ſoluble in any ſenſible degree: The malats are a medium between the oxalats and acetites, with reſpect to ſolubility, and the malic acid is in the middle degree of ſaturation between the oxalic and acetous acids. With this, as with all the acids, the metals require to be oxydated previous to ſolution.

The ancient chemiſts knew hardly any of the ſalts formed by the combinations of acetous acid with the ſalifiable baſes, except the acetites of potaſh, ſoda, ammoniac, copper, and lead. Mr Cadet diſcovered the acetite of arſenic *; Mr Wenzel, the Dijon academicians Mr de Laſſone, and Mr Prouſt, made us acquainted with the properties of the other acetites. From the property which acetite of potaſh poſſeſſes, of giving out ammoniac in diſtillation, there is ſome reaſon to ſuppoſe, that, beſides charcoal and hydrogen, the acetous radical contains a ſmall proportion of azote, though it is not impoſſible but the above production of ammoniac may be occaſioned by the decompoſition of the potaſh.

---

* Savans Etrangers, Vol. III.

TABLE *of the Combinations of Acetic Acid with the Salifiable Baſes, in the order of affinity.*

Baſes.	*Neutral Salts.*
Barytes	Acetat of barytes.
Potaſh	potaſh.
Soda	ſoda.
Lime	lime.
Magneſia	magneſia.
Ammoniac	ammoniac.
Oxyd of zinc	zinc.
manganeſe	manganeſe.
iron	iron.
lead	lead.
tin	tin.
cobalt	cobalt.
copper	copper.
nickel	nickel.
arſenic	arſenic.
biſmuth	biſmuth.
mercury	mercury.
antimony	antimony.
ſilver	ſilver.
gold	gold.
platina	platina.
Argill	argill.

SECT.

Note.—All theſe ſalts were unknown to the ancients; and even thoſe chemiſts who are moſt verſant in modern diſcoveries, are yet at a loſe whether the greater part of the ſalts produced by the oxygenated acetic radical belong properly to the claſs of acetites, or to that of acetats.—A.

Sect. XXXIV.—*Obſervations upon Acetic Acid, and its Combinations.*

We have given to radical vinegar the name of acetic acid, from ſuppoſing that it conſiſts of the ſame radical with that of the acetous acid, but more highly ſaturated with oxygen. According to this idea, acetic acid is the higheſt degree of oxygenation of which the hydro-carbonous radical is ſuſceptible; but, although this circumſtance be extremely probable, it requires to be confirmed by farther, and more deciſive experiments, before it be adopted as an abſolute chemical truth. We procure this acid as follows: Upon three parts acetite of potaſh or of copper, pour one part of concentrated ſulphuric acid, and, by diſtillation, a very highly concentrated vinegar is obtained, which we call acetic acid, formerly named radical vinegar. It is not hitherto rigorouſly proved that this acid is more highly oxygenated than the acetous acid, nor that the difference between them may not conſiſt in a different proportion between the elements of the radical or baſe.

TABLE *of the Combinations of Succinic Acid with the Salifiable Baſes, in the order of Affinity.*

Baſes.	*Neutral Salts.*
Barytes	Succinat of barytes.
Lime	lime.
Potaſh	potaſh.
Soda	ſoda.
Ammoniac	ammoniac.
Magneſia	magneſia.
Argill	argill.
Oxyd of zinc	zinc.
iron	iron.
manganeſe	manganeſe.
cobalt	cobalt.
nickel	nickel.
lead	lead.
tin	tin.
copper	copper.
biſmuth	biſmuth.
antimony	antimony.
arſenic	arſenic.
mercury	mercury.
ſilver	ſilver.
gold	gold.
platina	platina.

Note.—All the ſuccinats were unknown to the ancient chemiſts.—A.

SECT. XXXV.—*Obſervations upon Succinic Acid, and its Combinations.*

The ſuccinic acid is drawn from amber by ſublimation in a gentle heat, and riſes in a concrete form into the neck of the ſubliming veſſel. The operation muſt not be puſhed too far, or by too ſtrong a fire, otherwiſe the oil of the amber riſes alongſt with the acid. The ſalt is dried upon blotting paper, and purified by repeated ſolution and criſtallization.

This acid is ſoluble in twenty-four times its weight of cold water, and in a much ſmaller quantity of hot water. It poſſeſſes the qualities of an acid in a very ſmall degree, and only affects the blue vegetable colours very ſlightly. The affinities of this acid, with the ſalifiable baſes, are taken from Mr de Morveau, who is the firſt chemiſt that has endeavoured to aſcertain them.

SECT. XXXVI.—*Obſervations upon Benzoic Acid, and its Combinations with Salifiable Baſes* *.

This acid was known to the ancient chemiſts under the name of Flowers of Benjamin, or of Benzoin, and was procured, by ſublimation, from the gum or reſin called Benzoin: The means of procuring it, *via humida*, was diſcovered by Mr Geoffroy, and perfected by Mr Scheele. Upon benzoin, reduced to powder, pour ſtrong lime-water, having rather an exceſs of lime; keep the mixture continually ſtirring, and, after half an hour's digeſtion, pour off the liquor, and uſe freſh portions of lime-water in the ſame manner, ſo long as there is any appearance of neutralization. Join all the decanted liquors, and evaporate, as far as poſſible, without occaſioning criſtallization, and, when the liquor is cold, drop in muriatic acid till no more precipitate is formed. By the former part of the proceſs a benzoat of lime is formed, and, by the latter, the muriatic acid combines with the lime, forming muriat of lime, which remains

---

* Theſe combinations are called Benzoats of Lime, Potaſh, Zinc, &c.; but, as the order of affinity is unknown, the alphabetical table is omitted, as unneceſſary.—E.

mains diſſolved, while the benzoic acid, being inſoluble, precipitates in a concrete ſtate.

Sect. XXXVII.—*Obſervations upon Camphoric Acid, and its Combinations with Salifiable Baſes* *.

Camphor is a concrete eſſential oil, obtained, by ſublimation, from a ſpecies of laurus which grows in China and Japan. By diſtilling nitric acid eight times from camphor, Mr Koſegarten converted it into an acid analogous to the oxalic; but, as it differs from that acid in ſome circumſtances, we have thought neceſſary to give it a particular name, till its nature be more completely aſcertained by farther experiment.

As camphor is a carbono-hydrous or hydro-carbonous radical, it is eaſily conceived, that, by oxygenation, it ſhould form oxalic, malic, and ſeveral other vegetable acids: This conjecture is rendered not improbable by the experiments of Mr Koſegarten; and the principal phenomena exhibited in the combinations of camphoric acid with the ſalifiable baſes, being very

---

* Theſe combinations, which were all unknown to the ancients, are called Camphorats. The table is omitted, as being only in alphabetical order.—E.

very ſimilar to thoſe of the oxalic and malic acids, lead me to believe that it conſiſts of a mixture of theſe two acids.

SECT. XXXVIII.—*Obſervations upon Gallic Acid, and its Combinations with Salifiable Baſes* [*].

The Gallic acid, formerly called Principle of Aſtringency, is obtained from gall nuts, either by infuſion or decoction with water, or by diſtillation with a very gentle heat. This acid has only been attended to within theſe few years. The Committee of the Dijon Academy have followed it through all its combinations, and give the beſt account of it hitherto produced. Its acid properties are very weak; it reddens the tincture of turnſol, decompoſes ſulphurets, and unites to all the metals when they have been previouſly diſſolved in ſome other acid. Iron, by this combination, is precipitated of a very deep blue or violet colour. The radical of this acid, if it deſerves the name of one, is hitherto entirely unknown; it is contained in oak

---

[*] Theſe combinations, which are called Gallats, were all unknown to the ancients; and the order of their affinity is not hitherto eſtabliſhed.—A.

oak willow, marſh iris, the ſtrawberry, nymphea, Peruvian bark, the flowers and bark of pomgranate, and in many other woods and barks.

Sect. XXXIX.—*Obſervations upon Lactic Acid, and its Combinations with Salifiable Baſes* *.

The only accurate knowledge we have of this acid is from the works of Mr Scheele. It is contained in whey, united to a ſmall quantity of earth, and is obtained as follows: Reduce whey to one eighth part of its bulk by evaporation, and filtrate, to ſeparate all its cheeſy matter; then add as much lime as is neceſſary to combine with the acid; the lime is afterwards diſengaged by the addition of oxalic acid, which combines with it into an inſoluble neutral ſalt. When the oxalat of lime has been ſeparated by decantation, evaporate the remaining liquor to the conſiſtence of honey; the lactic acid is diſſolved by alkohol, which does not unite with the ſugar of milk and other foreign matters; theſe

---

* Theſe combinations are called Lactats; they were all unknown to the ancient chemiſts, and their affinities have not yet been aſcertained.—A.

theſe are ſeparated by filtration from the alkohol and acid; and the alkohol being evaporated, or diſtilled off, leaves the lactic acid behind.

This acid unites with all the ſalifiable baſes forming ſalts which do not criſtallize; and it ſeems conſiderably to reſemble the acetous acid.

TABLE *of the Combinations of Saccholactic Acid with the Salifiable Baſes, in the Order of Affinity.*

Baſes,	*Neutral Salts.*
Lime	Saccholat of lime.
Barytes	barytes.
Magneſia	magneſia.
Potaſh	potaſh.
Soda	ſoda.
Ammoniac	ammoniac.
Argill	argill.
Oxyd of zinc	zinc.
manganeſe	manganeſe.
iron	iron.
lead	lead.
tin	tin.
cobalt	cobalt.
copper	copper.
nickel	nickel.
arſenic	arſenic.
biſmuth	biſmuth.
mercury	mercury.
antimony	antimony.
ſilver	ſilver.

Note.—All theſe were unknown to the ancient chemiſts.—A.

SECT. XL.—*Obſervations upon Saccholactic Acid, and its Combinations.*

A ſpecies of ſugar may be extracted, by evaporation, from whey, which has long been known in pharmacy, and which has a conſiderable reſemblance to that procured from ſugar canes. This ſaccharine matter, like ordinary ſugar, may be oxygenated by means of nitric acid: For this purpoſe, ſeveral portions of nitric acid are diſtilled from it; the remaining liquid is evaporated, and ſet to criſtallize, by which means criſtals of oxalic acid are procured; at the ſame time a very fine white powder precipitates, which is the ſaccholactic acid diſcovered by Scheele. It is ſuſceptible of combining with the alkalies, ammoniac, the earths, and even with the metals: Its action upon the latter is hitherto but little known, except that, with them, it forms difficultly ſoluble ſalts. The order of affinity in the table is taken from Bergman.

TABLE *of the Combinations of Formic Acid, with the Salifiable Baſes, in the Order of Affinity.*

Baſes.	*Neutral Salts.*
Barytes	Formiat of barytes.
Potaſh	potaſh.
Soda	ſoda.
Lime	lime.
Magneſia	magneſia.
Ammoniac	ammoniac.
Oxyd of	
zinc	zinc.
manganeſe	manganeſe.
iron	iron.
lead	lead.
tin	tin.
cobalt	cobalt.
copper	copper.
nickel	nickel.
biſmuth	biſmuth.
ſilver	ſilver.
Argill	argill.

SECT.

Note.—All unknown to the ancient chemiſts.—A.

SECT. XLI.—*Obſervations upon Formic Acid, and its Combinations.*

This acid was firſt obtained by diſtillation from ants, in the laſt century, by Samuel Fiſher. The ſubject was treated of by Margraff in 1749, and by Meſſrs Ardwiſſon and Ochrn of Leipſic in 1777. The formic acid is drawn from a large ſpecies of red ants, *formica rufa, Lin.* which form large ant hills in woody places. It is procured, either by diſtilling the ants with a gentle heat in a glaſs retort or an alembic; or, after having waſhed the ants in cold water, and dried them upon a cloth, by pouring on boiling water, which diſſolves the acid; or the acid may be procured by gentle expreſſion from the inſects, in which caſe it is ſtronger than in any of the former ways. To obtain it pure, we muſt rectify, by means of diſtillation, which ſeparates it from the uncombined oily and charry matter; and it may be concentrated by freezing, in the manner recommended for treating the acetous acid.

Sect. XLII.—*Obſervations upon Bombic Acid, and its Combinations with Acidifiable Baſes* *.

The juices of the ſilk worm ſeem to aſſume an acid quality when that inſect changes from a larva to a chryſalis. At the moment of its eſcape from the latter to the butterfly form, it emits a reddiſh liquor which reddens blue paper, and which was firſt attentively obſerved by Mr Chauſſier of the Dijon academy, who obtains the acid by infuſing ſilk worm chryſalids in alkohol, which diſſolves their acid without being charged with any of the gummy parts of the inſect; and, by evaporating the alkohol, the acid remains tollerably pure. The properties and affinities of this acid are not hitherto aſcertained with any preciſion; and we have reaſon to believe that analogous acids may be procured from other inſects. The radical of this acid is probably, like that of the other acids from the animal kingdom, compoſed of charcoal, hydrogen, and azote, with the addition, perhaps, of phoſphorus.

Table

---

* Theſe combinations named Bombats were unknown to the ancient chemiſts; and the affinities of the ſalifiable baſes with the bombic acid are hitherto undetermined.—A.

TABLE *of the Combinations of the Sebacic Acid, with the Salifiable Baſes, in the Order of Affinity.*

Baſes.	*Neutral Salts.*
Barytes	Sebat of barytes.
Potaſh	potaſh.
Soda	ſoda.
Lime	lime.
Magneſia	magneſia.
Ammoniac	ammoniac.
Argill	argill.
Oxyd of	
zinc	zinc.
manganeſe	manganeſe.
iron	iron.
lead	lead
tin	tin.
cobalt	cobalt.
copper	copper.
nickel	nickel.
arſenic	arſenic.
biſmuth	biſmuth.
mercury	mercury.
antimony	antimony.
ſilver	ſilver.

Note.—All theſe were unknown to the ancient chemiſts.—A.

SECT. XLIII.—*Obſervations upon Sebacid Acid, and its Combinations.*

To obtain the ſebacic acid, let ſome ſuet be melted in a ſkillet over the fire, alongſt with ſome quick-lime in fine powder, and conſtantly ſtirred, raiſing the fire towards the end of the operation, and taking care to avoid the vapours, which are very offenſive. By this proceſs the ſebacic acid unites with the lime into a ſebat of lime, which is difficultly ſoluble in water; it is, however, ſeparated from the fatty matters with which it is mixed by ſolution in a large quantity of boiling water. From this the neutral ſalt is ſeparated by evaporation; and, to render it pure, is calcined, rediſſolved, and again criſtallized. After this we pour on a proper quantity of ſulphuric acid, and the ſebacic acid paſſes over by diſtillation.

SECT.

SECT. XLIV.—*Obſervations upon the Lithic Acid, and its Combinations with the Salifiable Baſes* *.

From the later experiments of Bergman and Scheele, the urinary calculus appears to be a ſpecies of ſalt with an earthy baſis; it is ſlightly acidulous, and requires a large quantity of water for ſolution, three grains being ſcarcely ſoluble in a thouſand grains of boiling water, and the greater part again criſtallizes when cold. To this concrete acid, which Mr de Morveau calls Lithiaſic Acid, we give the name of Lithic Acid, the nature and properties of which are hitherto very little known. There is ſome appearance that it is an acidulous neutral ſalt, or acid combined in exceſs with a ſalifiable baſe; and I have reaſon to believe that it really is an acidulous phoſphat of lime; if ſo, it muſt be excluded from the claſs of peculiar acids.

---

* All the combinations of this acid, ſhould it finally turn out to be one, were unknown to the ancient chemiſts, and its affinities with the ſalifiable baſes have not been hitherto determined.—A.

Table *of the Combinations of the Pruſſic Acid with the Salifiable Baſes, in the order of affinity.*

Baſes.	*Neutral Salts.*
Potaſh	Pruſſiat of potaſh.
Soda	ſoda.
Ammoniac	ammoniac.
Lime	lime.
Barytes	barytes.
Magneſia	magneſia.
Oxyd of zinc	zinc.
iron	iron.
manganeſe	manganeſe.
cobalt	cobalt.
nickel	nickel.
lead	lead.
tin	tin.
copper	copper.
biſmuth	biſmuth.
antimony	antimony.
arſenic	arſenic.
ſilver	ſilver.
mercury	mercury.
gold	gold.
platina	platina.

Obſer-

Note.——All theſe were unknown to former chemiſts.—A.

Obſervations upon the Pruſſic Acid, and its Combinations.

As the experiments which have been made hitherto upon this acid ſeem ſtill to leave a conſiderable degree of uncertainty with regard to its nature, I ſhall not enlarge upon its properties, and the means of procuring it pure and diſſengaged from combination. It combines with iron, to which it communicates a blue colour, and is equally ſuſceptible of entering into combination with moſt of the other metals, which are precipitated from it by the alkalies, ammoniac, and lime, in conſequence of greater affinity. The Pruſſic radical, from the experiments of Scheele, and eſpecially from thoſe of Mr Berthollet, ſeems compoſed of charcoal and azote; hence it is an acid with a double baſe. The phoſphorus which has been found combined with it appears, from the experiments of Mr Haſſenfratz, to be only accidental.

Although this acid combines with alkalies, earths, and metals, in the ſame way with other acids, it poſſeſſes only ſome of the properties we have been in uſe to attribute to acids, and it may conſequently be improperly ranked here in the claſs of acids; but, as I have already obſerved, it is difficult to form a decided opinion upon the nature of this ſubſtance until the ſubject has been farther elucidated by a greater number of experiments.

PART III.

Deſcription of the Inſtruments and Operations of Chemiſtry.

INTRODUCTION.

IN the two former parts of this work I deſignedly avoided being particular in deſcribing the manual operations of chemiſtry, becauſe I had found from experience, that, in a work appropriated to reaſoning, minute deſcriptions of proceſſes and of plates interrupt the chain of ideas, and render the attention neceſſary both difficult and tedious to the reader. On the other hand, if I had confined myſelf to the ſummary deſcriptions hitherto given, beginners could have only acquired very vague conceptions of practical chemiſtry from my work, and muſt have wanted both confidence and intereſt in operations they could neither repeat nor thoroughly

thoroughly comprehend. This want could not have been ſupplied from books; for, beſides that there are not any which deſcribe the modern inſtruments and experiments ſufficiently at large, any work that could have been conſulted would have preſented theſe things under a very different order of arrangement, and in a different chemical language, which muſt greatly tend to injure the main object of my performance.

Influenced by theſe motives, I determined to reſerve, for a third part of my work, a ſummary deſcription of all the inſtruments and manipulations relative to elementary chemiſtry. I conſidered it as better placed at the end, rather than at the beginning of the book, becauſe I muſt have been obliged to ſuppoſe the reader acquainted with circumſtances which a beginner cannot know, and muſt therefore have read the elementary part to become acquainted with. The whole of this third part may therefore be conſidered as reſembling the explanations of plates which are uſually placed at the end of academic memoirs, that they may not interrupt the connection of the text by lengthened deſcription. Though I have taken great pains to render this part clear and methodical, and have not omitted any eſſential inſtrument or apparatus, I am far from pretending by it to ſet aſide the neceſſity of attendance upon lectures and laboratories,

boratories, for ſuch as wiſh to acquire accurate knowledge of the ſcience of chemiſtry. Theſe ſhould familiariſe themſelves to the employment of apparatus, and to the performance of experiments by actual experience. *Nihil eſt in intellectu quod non prius fuerit in ſenſu*, the motto which the celebrated Rouelle cauſed to be painted in large characters in a conſpicuous part of his laboratory, is an important truth never to be loſt ſight of either by teachers or ſtudents of chemiſtry.

Chemical operations may be naturally divided into ſeveral claſſes, according to the purpoſes they are intended for performing. Some may be conſidered as purely mechanical, ſuch as the determination of the weight and bulk of bodies, trituration, levigation, ſearching, waſhing, filtration, &c. Others may be conſidered as real chemical operations, becauſe they are performed by means of chemical powers and agents; ſuch are ſolution, fuſion, &c. Some of theſe are intended for ſeparating the elements of bodies from each other, ſome for reuniting theſe elements together; and ſome, as combuſtion, produce both theſe effects during the ſame proceſs.

Without rigorouſly endeavouring to follow the above method, I mean to give a detail of the chemical operations in ſuch order of arrangement as ſeemed beſt calculated for conveying

veying inſtruction. I ſhall be more particular in deſcribing the apparatus connected with modern chemiſtry, becauſe theſe are hitherto little known by men who have devoted much of their time to chemiſtry, and even by many profeſſors of the ſcience.

CHAP. I.

Of the Inſtruments neceſſary for determining the Abſolute and Specific Gravities of Solid and Liquid Bodies.

THE beſt method hitherto known for determining the quantities of ſubſtances ſubmitted to chemical experiment, or reſulting from them, is by means of an accurately conſtructed beam and ſcales, with properly regulated weights, which well known operation is called *weighing*. The denomination and quantity of the weights uſed as an unit or ſtandard for this purpoſe are extremely arbitrary, and vary not only in different kingdoms, but even in different provinces of the ſame kingdom, and in different cities of the ſame province. This variation is of infinite conſequence to be well underſtood in commerce and in the arts; but, in chemiſtry, it is of no moment what particular denomination of weight be employed, provided the reſults of experiments be expreſſed in convenient fractions of the ſame denomination. For this purpoſe, until all the weights uſed in ſociety be reduced to the ſame ſtandard, it will be ſufficient for chemiſts in different parts to uſe the common pound

pound of their own country as the unit or ſtandard, and to expreſs all its fractional parts in decimals, inſtead of the arbitrary diviſions now in uſe. By this means the chemiſts of all countries will be thoroughly underſtood by each other, as, although the abſolute weights of the ingredients and products cannot be known, they will readily, and without calculation, be able to determine the relative proportions of theſe to each other with the utmoſt accuracy; ſo that in this way we ſhall be poſſeſſed of an univerſal language for this part of chemiſtry.

With this view I have long projected to have the pound divided into decimal fractions, and I have of late ſucceeded through the aſſiſtance of Mr Fourche balance-maker at Paris, who has executed it for me with great accuracy and judgment. I recommend to all who carry on experiments to procure ſimilar diviſions of the pound, which they will find both eaſy and ſimple in its application, with a very ſmall knowledge of decimal fractions *.

As

---

* Mr Lavoiſier gives, in this part of his work, very accurate directions for reducing the common ſubdiviſions of the French pound into decimal fractions, and *vice verſa*, by means of tables ſubjoined to this 3d part. As theſe inſtructions, and the table, would be uſeleſs to the Britiſh chemiſt, from the difference between the ſubdiviſions of the French and Troy pounds, I have omitted them, but have ſubjoined in the appendix accurate rules for converting the one into the other.—E.

As the uſefulneſs and accuracy of chemiſtry depends entirely upon the determination of the weights of the ingredients and products both before and after experiments, too much preciſion cannot be employed in this part of the ſubject; and, for this purpoſe, we muſt be provided with good inſtruments. As we are often obliged, in chemical proceſſes, to aſcertain, within a grain or leſs, the tare or weight of large and heavy inſtruments, we muſt have beams made with peculiar niceneſs by accurate workmen, and theſe muſt always be kept apart from the laboratory in ſome place where the vapours of acids, or other corroſive liquors, cannot have acceſs, otherwiſe the ſteel will ruſt, and the accuracy of the balance be deſtroyed. I have three ſets, of different ſizes, made by Mr Fontin with the utmoſt nicety, and, excepting thoſe made by Mr Ramſden of London, I do not think any can compare with them for preciſion and ſenſibility. The largeſt of theſe is about three feet long in the beam for large weights, up to fifteen or twenty pounds; the ſecond, for weights of eighteen or twenty ounces, is exact to a tenth part of a grain; and the ſmalleſt, calculated only for weighing about one gros, is ſenſibly affected by the five hundredth part of a grain.

Beſides theſe nicer balances, which are only uſed for experiments of reſearch, we muſt have

others

others of leſs value for the ordinary purpoſes of the laboratory. A large iron balance, capable of weighing forty or fifty pounds within half a dram, one of a middle ſize, which may aſcertain eight or ten pounds, within ten or twelve grains, and a ſmall one, by which about a pound may be determined, within one grain.

We muſt likewiſe be provided with weights divided into their ſeveral fractions, both vulgar and decimal, with the utmoſt nicety, and verified by means of repeated and accurate trials in the niceſt ſcales; and it requires ſome experience, and to be accurately acquainted with the different weights, to be able to uſe them properly. The beſt way of preciſely aſcertaining the weight of any particular ſubſtance is to weigh it twice, once with the decimal diviſions of the pound, and another time with the common ſubdiviſions or vulgar fractions, and, by comparing theſe, we attain the utmoſt accuracy.

By the ſpecific gravity of any ſubſtance is underſtood the quotient of its abſolute weight divided by its magnitude, or, what is the ſame, the weight of a determinate bulk of any body. The weight of a determinate magnitude of water has been generally aſſumed as unity for this purpoſe; and we expreſs the ſpecific gravity of gold, ſulphuric acid, &c. by ſaying, that gold is nineteen times, and ſulphuric acid twice the weight of water, and ſo of other bodies.

It is the more convenient to aſſume water as unity in ſpecific gravities, that thoſe ſubſtances whoſe ſpecific gravity we wiſh to determine, are moſt commonly weighed in water for that purpoſe. Thus, if we wiſh to determine the ſpecific gravity of gold flattened under the hammer, and ſuppoſing the piece of gold to weigh 8 *oz.* 4 *gros* 2½ *grs.* in the air *, it is ſuſpended by means of a fine metallic wire under the ſcale of a hydroſtatic balance, ſo as to be entirely immerſed in water, and again weighed. The piece of gold in Mr Briſſon's experiment loſt by this means 3 *gros* 37 *grs.*; and, as it is evident that the weight loſt by a body weighed in water is preciſely equal to the weight of the water diſplaced, or to that of an equal volume of water, we may conclude, that, in equal magnitudes, gold weighs 4893½ *grs.* and water 253 *grs.* which, reduced to unity, gives 1.0000 as the ſpecific gravity of water, and 19.3617 for that of gold. We may operate in the ſame manner with all ſolid ſubſtances. We have rarely any occaſion, in chemiſtry, to determine the ſpecific gravity of ſolid bodies, unleſs when operating upon alloys or metallic glaſſes; but we have very frequent neceſſity to aſcertain that of fluids, as it is often the only means of judging of their purity or degree of concentration.

This

---

* Vide Mr Briſſon's Eſſay upon Specific Gravity, p. 5.—A.

This object may be very fully accompliſhed with the hydroſtatic balance, by weighing a ſolid body; ſuch, for example, as a little ball of rock criſtal ſuſpended by a very fine gold wire, firſt in the air, and afterwards in the fluid whoſe ſpecific gravity we wiſh to diſcover. The weight loſt by the criſtal, when weighed in the liquor, is equal to that of an equal bulk of the liquid. By repeating this operation ſucceſſively in water and different fluids, we can very readily aſcertain, by a ſimple and eaſy calculation, the relative ſpecific gravities of theſe fluids, either with reſpect to each other or to water. This method is not, however, ſufficiently exact, or, at leaſt, is rather troubleſome, from its extreme delicacy, when uſed for liquids differing but little in ſpecific gravity from water; ſuch, for inſtance, as mineral waters, or any other water containing very ſmall portions of ſalt in ſolution.

In ſome operations of this nature, which have not hitherto been made public, I employed an inſtrument of great ſenſibility for this purpoſe with great advantage. It conſiſts of a hollow cylinder, *Abcf*, Pl. vii. fig. 6. of braſs, or rather of ſilver, loaded at its bottom, bcf, with tin, as repreſented ſwimming in a jug of water, *lmno*. To the upper part of the cylinder is attached a ſtalk of ſilver wire, not more than three fourths of a line diameter, ſurmounted by a little cup *d*, intended for containing weights; upon the ſtalk a mark is made at *g*, the uſe of which we ſhall preſently explain. This cylinder may be made of any ſize; but, to be accurate, ought at leaſt to diſplace four pounds of water. The weight of tin with which this inſtrument is loaded ought to be ſuch as will make it remain almoſt in equilibrium in diſtilled water, and ſhould not require more than half a dram, or a dram at moſt, to make it ſink to *g*.

We muſt firſt determine, with great preciſion, the exact weight of the inſtrument, and the number of additional grains requiſite for making it ſink, in diſtilled water of a determinate temperature, to the mark: We then perform the ſame experiment upon all the fluids of which we wiſh to aſcertain the ſpecific gravity, and, by means of calculation, reduce the obſerved differences to a common ſtandard of cubic feet, pints or pounds, or of decimal fractions, comparing them with water. This method, joined to experiments with certain reagents *, is one of the beſt for determining the quality of waters, and is even capable of pointing out differences which eſcape the moſt accurate chemical analyſis. I ſhall, at ſome future period,

---

* For the uſe of theſe reagents ſee Bergman's excellent treatiſe upon the analyſis of mineral waters, in his Chemical and Phyſical Eſſays.—E.

period, give an account of a very extenſive ſet of experiments which I have made upon this ſubject.

Theſe metallic hydrometers are only to be uſed for determining the ſpecific gravities of ſuch waters as contain only neutral ſalts or alkaline ſubſtances; and they may be conſtructed with different degrees of ballaſt for alkohol and other ſpiritous liquors. When the ſpecific gravities of acid liquors are to be aſcertained, we muſt uſe a glaſs hydrometer, as repreſented Pl. vii. fig. 14 †. This conſiſts of a hollow cylinder of glaſs, *a b c f*, hermetically ſealed at its lower end, and drawn out at the upper into a capillary tube *a*, ending in the little cup or baſon *d*. This inſtrument is ballaſted with more or leſs mercury, at the bottom of the cylinder introduced through the tube, in proportion to the weight of the liquor intended to be examined: We may introduce a ſmall graduated ſlip of paper into the tube *a d;* and, though theſe degrees do not exactly correſpond to the fractions of grains in the different liquors, they may be rendered very uſeful in calculation.

What is ſaid in this chapter may ſuffice, without farther enlargement, for indicating the means

---

† Three or four years ago, I have ſeen ſimilar glaſs hydrometers, made for Dr Black by B. Knie, a very ingenious artiſt of this city.—E.

means of aſcertaining the abſolute and ſpecific gravities of ſolids and fluids, as the neceſſary inſtruments are generally known, and may eaſily be procured: But, as the inſtruments I have uſed for meaſuring the gaſſes are not any where deſcribed, I ſhall give a more detailed account of theſe in the following chapter.

CHAP. II.

Of Gazometry, or the Meaſurement of the Weight and Volume of Aëriform Subſtances.

SECT. I.

Deſcription of the Pneumato-chemical Apparatus.

THE French chemiſts have of late applied the name of *pneumato-chemical apparatus* to the very ſimple and ingenious contrivance, invented by Dr Prieſtley, which is now indiſpenſibly neceſſary to every laboratory. This conſiſts of a wooden trough, of larger or ſmaller dimenſions as is thought convenient, lined with plate-lead or tinned copper, as repreſented in perſpective, Pl. V. In Fig. 1. the ſame trough or ciſtern is ſuppoſed to have two of its ſides cut away, to ſhow its interior conſtruction more diſtinctly. In this apparatus, we diſtinguiſh between the ſhelf ABCD Fig. 1. and 2. and the bottom or body of the ciſtern FGHI Fig. 2. The

The jars or bell-glaſſes are filled with water in this deep part, and, being turned with their mouths downwards, are afterwards ſet upon the ſhelf ABCD, as ſhown Plate X. Fig. 1. F. The upper parts of the ſides of the ciſtern above the level of the ſhelf are called the *rim* or *borders*.

The ciſtern ought to be filled with water, ſo as to ſtand at leaſt an inch and a half deep upon the ſhelf, and it ſhould be of ſuch dimenſions as to admit of at leaſt one foot of water in every direction in the well. This ſize is ſufficient for ordinary occaſions; but it is often convenient, and even neceſſary, to have more room; I would therefore adviſe ſuch as intend to employ themſelves uſefully in chemical experiments, to have this apparatus made of conſiderable magnitude, where their place of operating will allow. The well of my principal ciſtern holds four cubical feet of water, and its ſhelf has a ſurface of fourteen ſquare feet; yet, in ſpite of this ſize, which I at firſt thought immoderate, I am often ſtraitened for room.

In laboratories, where a conſiderable number of experiments are performed, it is neceſſary to have ſeveral leſſer ciſterns, beſides the large one, which may be called the *general magazine;* and even ſome portable ones, which may be moved when neceſſary, near a furnace, or wherever they may be wanted. There are likewiſe ſome operations which dirty the water of the apparatus,

tus, and therefore require to be carried on in ciſterns by themſelves.

It were doubtleſs conſiderably cheaper to uſe ciſterns, or iron-bound tubs, of wood ſimply dove-tailed, inſtead of being lined with lead or copper; and in my firſt experiments I uſed them made in that way; but I ſoon diſcovered their inconvenience. If the water be not always kept at the ſame level, ſuch of the dovetails as are left dry ſhrink, and, when more water is added, it eſcapes through the joints, and runs out.

We employ criſtal jars or bell glaſſes, Pl. V. Fig. 9. A. for containing the gaſſes in this apparatus; and, for tranſporting theſe, when full of gas, from one ciſtern to another, or for keeping them in reſerve when the ciſtern is too full, we make uſe of a flat diſh BC, ſurrounded by a ſtanding up rim or border, with two handles DE for carrying it by.

After ſeveral trials of different materials, I have found marble the beſt ſubſtance for conſtructing the mercurial pneumato-chemical apparatus, as it is perfectly impenetrable by mercury, and is not liable, like wood, to ſeparate at the junctures, or to allow the mercury to eſcape through chinks; neither does it run the riſk of breaking, like glaſs, ſtone-ware, or porcelain. Take a block of marble BCDE, Plate V. Fig. 3. and 4. about two feet long, 15 or 18 inches broad,

broad, and ten inches thick, and cauſe it to be hollowed out as at *m n* Fig. 5. about four inches deep, as a reſervoir for the mercury; and, to be able more conveniently to fill the jars, cut the gutter T V, Fig. 3. 4. and 5. at leaſt four inches deeper; and, as this trench may ſometimes prove troubleſome, it is made capable of being covered at pleaſure by thin boards, which ſlip into the grooves *x y*, Fig. 5. I have two marble ciſterns upon this conſtruction, of different ſizes, by which I can always employ one of them as a reſervoir of mercury, which it preſerves with more ſafety than any other veſſel, being neither ſubject to overturn, nor to any other accident. We operate with mercury in this apparatus exactly as with water in the one before deſcribed; but the bell-glaſſes muſt be of ſmaller diameter, and much ſtronger; or we may uſe glaſs tubes, having their mouths widened, as in Fig. 7.; theſe are called *eudiometers* by the glaſs-men who ſell them. One of the bell-glaſſes is repreſented Fig. 5. A. ſtanding in its place, and what is called a jar is engraved Fig. 6.

The mercurial pneumato-chemical apparatus is neceſſary in all experiments wherein the diſengaged gaſſes are capable of being abſorbed by water, as is frequently the caſe, eſpecially in all combinations, excepting thoſe of metals, in fermentation, &c.

SECT. II.

Of the Gazometer.

I give the name of *gazometer* to an inſtrument which I invented, and cauſed conſtruct, for the purpoſe of a kind of bellows, which might furniſh an uniform and continued ſtream of oxygen gas in experiments of fuſion. Mr Meuſnier and I have ſince made very conſiderable corrections and additions, having converted it into what may be called an *univerſal inſtrument*, without which it is hardly poſſible to perform moſt of the very exact experiments. The name we have given the inſtrument indicates its intention for meaſuring the volume or quantity of gas ſubmitted to it for examination.

It conſiſts of a ſtrong iron beam, DE, Pl. VIII. Fig. 1. three feet long, having at each end, D and E, a ſegment of a circle, likewiſe ſtrongly conſtructed of iron, and very firmly joined. Inſtead of being poiſed as in ordinary balances, this beam reſts, by means of a cylindrical axis of poliſhed ſteel, F, Fig. 9. upon two large moveable braſs friction-wheels, by which the reſiſtance to its motion from friction is conſiderably diminiſhed, being converted into friction of of the ſecond order. As an additional precaution, the parts of theſe wheels which ſupport the axis of the beam are covered with plates of poliſhed rock-criſtal. The whole of this machinery is fixed to the top of the ſolid column of wood BC, Fig. 1. To one extremity D of the beam, a ſcale P for holding weights is ſuſpended by a flat chain, which applies to the curvature of the arc *n*D*o*, in a groove made for the purpoſe. To the other extremity E of the beam is applied another flat chain, *i k m*, ſo conſtructed, as to be incapable of lengthening or ſhortening, by being leſs or more charged with weight; to this chain, an iron trivet, with three branches, *a i*, *c i*, and *h i*, is ſtrongly fixed at *i*, and theſe branches ſupport a large inverted jar A, of hammered copper, of about 18 inches diameter, and 20 inches deep. The whole of this machine is repreſented in perſpective, Pl. VIII. Fig. 1. and Pl. IX. Fig. 2. and 4. give perpendicular ſections, which ſhow its interior ſtructure.

Round the bottom of the jar, on its outſide, is fixed (Pl. IX. Fig. 2.) a border divided into compartments 1, 2, 3, 4, &c. intended to receive leaden weights ſeparately repreſented 1, 2, 3, Fig. 3. Theſe are intended for increaſing the weight of the jar when a conſiderable preſſure is requiſite, as will be afterwards explained, though ſuch neceſſity ſeldom occurs.

The

The cylindrical jar A is entirely open below, *de*, Pl. IX. Fig. 4.; but is cloſed above with a copper lid, *a b c*, open at *b f*, and capable of being ſhut by the cock *g*. This lid, as may be ſeen by inſpecting the figures, is placed a few inches within the top of the jar to prevent the jar from being ever entirely immerſed in the water, and covered over. Were I to have this inſtrument made over again, I ſhould cauſe the lid to be conſiderably more flattened, ſo as to be almoſt level. This jar or reſervoir of air is contained in the cylindrical copper veſſel, LMNO, Pl. VIII. Fig. 1. filled with water.

In the middle of the cylindrical veſſel LMNO, Pl. IX. Fig. 4. are placed two tubes *st*, *xy*, which are made to approach each other at their upper extremities *t y*; theſe are made of ſuch a length as to riſe a little above the upper edge LM of the veſſel LMNO, and when the jar *abcde* touches the bottom NO, their upper ends enter about half an inch into the conical hollow *b*, leading to the ſtop-cock *g*.

The bottom of the veſſel LMNO is repreſented Pl. IX. Fig. 3. in the middle of which a ſmall hollow ſemiſpherical cap is ſoldered, which may be conſidered as the broad end of a funnel reverſed; the two tubes *st*, *xy*, Fig. 4. are adapted to this cap at *s* and *x*, and by this means communicate with the tubes *mm*, *nn*, *oo*, *pp*, Fig. 3. which are fixed horizontally upon the bottom

bottom of the veſſel, and all of which terminate in, and are united by, the ſpherical cap *sx*. Three of theſe tubes are continued out of the veſſel, as in Pl. VIII. Fig. 1. The firſt marked in that figure 1, 2, 3, is inſerted at its extremity 3, by means of an intermediate ſtop-cock 4, to the jar V. which ſtands upon the ſhelf of a ſmall pneumato-chemical apparatus GHIK, the inſide of which is ſhown Pl. IX. Fig. 1. The ſecond tube is applied againſt the outſide of the veſſel LMNO from 6 to 7, is continued at 8, 9, 10, and at 11 is engaged below the jar V. The former of theſe tubes is intended for conveying gas into the machine, and the latter for conducting ſmall quantities for trials under jars. The gas is made either to flow into or out of the machine, according to the degree of preſſure it receives; and this preſſure is varied at pleaſure, by loading the ſcale P leſs or more, by means of weights. When gas is to be introduced into the machine, the preſſure is taken off, or even rendered negative; but, when gas is to be expelled, a preſſure is made with ſuch degree of force as is found neceſſary.

The third tube 12, 13, 14, 15, is intended for conveying air or gas to any neceſſary place or apparatus for combuſtions, combinations, or any other experiment in which it is required.

To explain the uſe of the fourth tube, I muſt enter into ſome diſcuſſions. Suppoſe the veſſel

ſel LMNO, Pl. VIII. Fig. 1. full of water, and the jar A partly filled with gas, and partly with water; it is evident that the weights in the baſon P may be ſo adjuſted, as to occaſion an exact equilibrium between the weight of the baſon and of the jar, ſo that the external air ſhall not tend to enter into the jar, nor the gas to eſcape from it; and in this caſe the water will ſtand exactly at the ſame level both within and without the jar. On the contrary, if the weight in the baſon P be diminiſhed, the jar will then preſs downwards from its own gravity, and the water will ſtand lower within the jar than it does without; in this caſe, the included air or gas will ſuffer a degree of compreſſion above that experienced by the external air, exactly proportioned to the weight of a column of water, equal to the difference of the external and internal ſurfaces of the water. From theſe reflections, Mr Meuſnier contrived a method of determining the exact degree of preſſure to which the gas contained in the jar is at any time expoſed. For this purpoſe, he employs a double glaſs ſyphon 19, 20, 21, 22, 23, firmly cemented at 19 and 23. The extremity 19 of this ſyphon communicates freely with the water in the external veſſel of the machine, and the extremity 23 communicates with the fourth tube at the bottom of the cylindrical veſſel, and conſequently, by means of the perpendicular tube

tube *st*, Pl. IX. Fig. 4. with the air contained in the jar. He likewiſe cements, at 16, Pl. VIII. Fig. 1. another glaſs tube 16, 17, 18, which communicates at 16 with the water in the exterior veſſel LMNO, and, at its upper end 18, is open to the external air.

By theſe ſeveral contrivances, it is evident that the water muſt ſtand in the tube 16, 17, 18, at the ſame level with that in the ciſtern LMNO; and, on the contrary, that, in the branch 19, 20, 21, it muſt ſtand higher or lower, according as the air in the jar is ſubjected to a greater or leſſer preſſure than the external air. To aſcertain theſe differences, a braſs ſcale divided into inches and lines is fixed between theſe two tubes. It is readily conceived that, as air, and all other elaſtic fluids, muſt increaſe in weight by compreſſion, it is neceſſary to know their degree of condenſation to be enabled to calculate their quantities, and to convert the meaſure of their volumes into correſpondent weights; and this object is intended to be fulfilled by the contrivance now deſcribed.

But, to determine the ſpecific gravity of air or of gaſſes, and to aſcertain their weight in a known volume, it is neceſſary to know their temperature, as well as the degree of preſſure under which they ſubſiſt; and this is accompliſhed by means of a ſmall thermometer, ſtrongly cemented into a braſs collet, which ſcrews into the lid of the jar A. This thermometer is repreſented ſeparately, Pl. VIII. Fig. 10. and in its place 24, 25, Fig. 1. and Pl. IX. Fig. 4. The bulb is in the inſide of the jar A, and its graduated ſtalk riſes on the outſide of the lid.

The practice of gazometry would ſtill have laboured under great difficulties, without farther precautions than thoſe above deſcribed. When the jar A ſinks in the water of the ciſtern LMNO, it muſt loſe a weight equal to that of the water which it diſplaces ; and conſequently the compreſſion which it makes upon the contained air or gas muſt be proportionally diminiſhed. Hence the gas furniſhed, during experiments from the machine, will not have the ſame denſity towards the end that it had at the beginning, as its ſpecific gravity is continually diminiſhing. This difference may, it is true, be determined by calculation ; but this would have occaſioned ſuch mathematical inveſtigations as muſt have rendered the uſe of this apparatus both troubleſome and difficult. Mr Meuſnier has remedied this inconvenience by the following contrivance. A ſquare rod of iron, 26, 27, Pl. VIII. Fig. 1. is raiſed perpendicular to the middle of the beam DE. This rod paſſes through a hollow box of braſs 28, which opens, and may be filled with lead ; and this box is made to ſlide alongſt the rod, by means of a toothed pinion playing in a rack, ſo as to raiſe

or

or lower the box, and to fix it at ſuch places as is judged proper.

When the lever or beam DE ſtands horizontal, this box gravitates to neither ſide; but, when the jar A ſinks into the ciſtern LMNO, ſo as to make the beam incline to that ſide, it is evident the loaded box 28, which then paſſes beyond the center of ſuſpenſion, muſt gravitate to the ſide of the jar, and augment its preſſure upon the included air. This is increaſed in proportion as the box is raiſed towards 27, becauſe the ſame weight exerts a greater power in proportion to the length of the lever by which it acts. Hence, by moving the box 28 alongſt the rod 26, 27, we can augment or diminiſh the correction it is intended to make upon the preſſure of the jar; and both experience and calculation ſhow that this may be made to compenſate very exactly for the loſs of weight in the jar at all degrees of preſſure.

I have not hitherto explained the moſt important part of the uſe of this machine, which is the manner of employing it for aſcertaining the quantities of the air or gas furniſhed during experiments. To determine this with the moſt rigorous preciſion, and likewiſe the quantity ſupplied to the machine from experiments, we fixed to the arc which terminates the arm of the beam E, Pl. VIII. Fig. 1. the braſs ſector *l m*, divided into degrees and half degrees; which

which conſequently moves in common with the beam; and the lowering of this end of the beam is meaſured by the fixed index 29, 30, which has a Nonius giving hundredth parts of a degree at its extremity 30.

The whole particulars of the different parts of the above deſcribed machine are repreſented in Plate VIII. as follow.

Fig. 2. Is the flat chain invented by Mr Vaucanſon, and employed for ſuſpending the ſcale or baſon P, Fig. 1; but, as this lengthens or ſhortens according as it is more or leſs loaded, it would not have anſwered for ſuſpending the jar A, Fig. 1.

Fig. 5. Is the chain *i k m*, which in Fig. 1. ſuſtains the jar A. This is entirely formed of plates of poliſhed iron interlaced into each other, and held together by iron pins. This chain does not lengthen in any ſenſible degree, by any weight it is capable of ſupporting.

Fig. 6. The trivet, or three branched ſtirrup, by which the jar A is hung to the balance, with the ſcrew by which it is fixed in an accurately vertical poſition.

Fig. 3. The iron rod 26, 27, which is fixed perpendicular to the center of the beam, with its box 28.

Fig. 7. & 8. The friction-wheels, with the plates of rock-criſtal Z, as points of contact by

by which the friction of the axis of the lever of the balance is avoided.

Fig. 4. The piece of metal which ſupports the axis of the friction-wheels.

Fig. 9. The middle of the lever or beam, with the axis upon which it moves.

Fig. 10. The thermometer for determining the temperature of the air or gas contained in the jar.

When this gazometer is to be uſed, the ciſtern or external veſſel, LMNO, Pl. VIII. Fig. 1. is to be filled with water to a determinate height, which ſhould be the ſame in all experiments. The level of the water ſhould be taken when the beam of the balance ſtands horizontal; this level, when the jar is at the bottom of the ciſtern, is increaſed by all the water which it diſplaces, and is diminiſhed in proportion as the jar riſes to its higheſt elevation. We next endeavour, by repeated trials, to diſcover at what elevation the box 28 muſt be fixed, to render the preſſure equal in all ſituations of the beam. I ſhould have ſaid nearly, becauſe this correction is not abſolutely rigorous; and differences of a quarter, or even of half a line, are not of any conſequence. This height of the box 28 is not the ſame for every degree of preſſure, but varies according as this is of one, two, three, or more inches. All theſe ſhould be regiſtered with great order and preciſion.

We next take a bottle which holds eight or ten pints, the capacity of which is very accurately determined by weighing the water it is capable of containing. This bottle is turned bottom upwards, full of water, in the ciſtern of the pneumato-chemical apparatus GHIK, Fig. 1. and is ſet on its mouth upon the ſhelf of the apparatus, inſtead of the glaſs jar V, having the extremity 11 of the tube 7, 8, 9, 10, 11, inſerted into its mouth. The machine is fixed at zero of preſſure, and the degree marked by the index 30 upon the ſector *ml* is accurately obſerved; then, by opening the ſtopcock 8, and preſſing a little upon the jar A, as much air is forced into the bottle as fills it entirely. The degree marked by the index upon the ſector is now obſerved, and we calculate what number of cubical inches correſpond to each degree. We then fill a ſecond and third bottle, and ſo on, in the ſame manner, with the ſame precautions, and even repeat the operation ſeveral times with bottles of different ſizes, till at laſt, by accurate attention, we aſcertain the exact gage or capacity of the jar A, in all its parts; but it is better to have it formed at firſt accurately cylindrical, by which we avoid theſe calculations and eſtimates.

The inſtrument I have been deſcribing was conſtructed with great accuracy and uncommon ſkill by Mr Meignie junior, engineer and phyſical

cal inſtrument-maker. It is a moſt valuable inſtrument, from the great number of purpoſes to which it is applicable; and, indeed, there are many experiments which are almoſt impoſſible to be performed without it. It becomes expenſive, becauſe, in many experiments, ſuch as the formation of water and of nitric acid, it is abſolutely neceſſary to employ two of the ſame machines. In the preſent advanced ſtate of chemiſtry, very expenſive and complicated inſtruments are become indiſpenſibly neceſſary for aſcertaining the analyſis and ſyntheſis of bodies with the requiſite preciſion as to quantity and proportion; it is certainly proper to endeavour to ſimplify theſe, and to render them leſs coſtly; but this ought by no means to be attempted at the expence of their conveniency of application, and much leſs of their accuracy.

SECT. III.

Some other methods of meaſuring the volume of Gaſſes.

The gazometer deſcribed in the foregoing ſection is too coſtly and too complicated for being generally uſed in laboratories for meaſuring the gaſſes, and is not even applicable to every circumſtance

circumſtance of this kind. In numerous ſeries of experiments, more ſimple and more readily applicable methods muſt be employed. For this purpoſe I ſhall deſcribe the means I uſed before I was in poſſeſſion of a gazometer, and which I ſtill uſe in preference to it in the ordinary courſe of my experiments.

Suppoſe that, after an experiment, there is a reſiduum of gas, neither abſorbable by alkali nor water, contained in the upper part of the jar AEF, Pl. IV. Fig. 3. ſtanding on the ſhelf of a pneumato-chemical apparatus, of which we wiſh to aſcertain the quantity, we muſt firſt mark the height to which the mercury or water riſes in the jar with great exactneſs, by means of ſlips of paper paſted in ſeveral parts round the jar. If we have been operating in mercury, we begin by diſplacing the mercury from the jar, by introducing water in its ſtead. This is readily done by filling a bottle quite full of water; having ſtopped it with your finger, turn it up, and introduce its mouth below the edge of the jar; then, turning down its body again, the mercury, by its gravity, falls into the bottle, and the water riſes in the jar, and takes the place occupied by the mercury. When this is accompliſhed, pour ſo much water into the ciſtern ABCD as will ſtand about an inch over the ſurface of the mercury; then paſs the diſh BC, Pl. V. Fig. 9. under the jar, and carry it to the water

water ciſtern, Fig. 1. and 2. We here exchange the gas into another jar, which has been previouſly graduated in the manner to be afterwards deſcribed; and we thus judge of the quantity or volume of the gas by means of the degrees which it occupies in the graduated jar.

There is another method of determining the volume of gas, which may either be ſubſtituted in place of the one above deſcribed, or may be uſefully employed as a correction or proof of that method. After the air or gas is exchanged from the firſt jar, marked with ſlips of paper, into the graduated jar, turn up the mouth of the marked jar, and fill it with water exactly to the marks EF, Pl. IV. Fig. 3. and by weighing the water we determine the volume of the air or gas it contained, allowing one cubical foot, or 1728 cubical inches, of water for each 70 pounds, French weight.

The manner of graduating jars for this purpoſe is very eaſy, and we ought to be provided with ſeveral of different ſizes, and even ſeveral of each ſize, in caſe of accidents. Take a tall, narrow, and ſtrong glaſs jar, and, having filled it with water in the ciſtern, Pl. V. Fig. 1. place it upon the ſhelf ABCD; we ought always to uſe the ſame place for this operation, that the level of the ſhelf may be always exactly ſimilar, by which almoſt the only error to which this proceſs is liable will be avoided. Then take a narrow mouthed phial which holds exactly 6 *oz.* 3 *gros* 61 *grs.* of water, which correſponds to 10 cubical inches. If you have not one exactly of this dimenſion, chooſe one a little larger, and diminiſh its capacity to the ſize requiſite, by dropping in a little melted wax and roſin. This bottle ſerves the purpoſe of a ſtandard for gaging the jars. Make the air contained in this bottle paſs into the jar, and mark exactly the place to which the water has deſcended; add another meaſure of air, and again mark the place of the water, and ſo on, till all the water be diſplaced. It is of great conſequence that, during the courſe of this operation, the bottle and jar be kept at the ſame temperature with the water in the ciſtern; and, for this reaſon, we muſt avoid keeping the hands upon either as much as poſſible; or, if we ſuſpect they have been heated, we muſt cool them by means of the water in the ciſtern. The height of the barometer and thermometer during this experiment is of no conſequence.

When the marks have been thus aſcertained upon the jar for every ten cubical inches, we engrave a ſcale upon one of its ſides, by means of a diamond pencil. Glaſs tubes are graduated in the ſame manner for uſing in the mercurial apparatus, only they muſt be divided into cubical inches, and tenths of a cubical inch. The bottle uſed for gaging theſe muſt hold

8 *oz.* 6 *gros* 25 *grs.* of mercury, which exactly correſponds to a cubical inch of that metal.

The method of determining the volume of air or gas, by means of a graduated jar, has the advantage of not requiring any correction for the difference of height between the ſurface of the water within the jar, and in the ciſtern; but it requires corrections with reſpect to the height of the barometer and thermometer. But, when we aſcertain the volume of air by weighing the water which the jar is capable of containing, up to the marks EF, it is neceſſary to make a farther correction, for the difference between the ſurface of the water in the ciſtern, and the height to which it riſes within the jar. This will be explained in the fifth ſection of this chapter.

SECT. IV.

Of the method of Separating the different Gaſſes from each other.

As experiments often produce two, three, or more ſpecies of gas, it is neceſſary to be able to ſeparate theſe from each other, that we may aſcertain the quantity and ſpecies of each. Suppoſe that under the jar A, Pl. IV. Fig. 3. is contained

contained a quantity of different gaſſes mixed together, and ſtanding over mercury, we begin by marking with ſlips of paper, as before directed, the height at which the mercury ſtands within the glaſs; then introduce about a cubical inch of water into the jar, which will ſwim over the ſurface of the mercury: If the mixture of gas contains any muriatic or ſulphurous acid gas, a rapid and conſiderable abſorption will inſtantly take place, from the ſtrong tendency theſe two gaſſes have, eſpecially the former, to combine with, or be abſorbed by water. If the water only produces a ſlight abſorption of gas hardly equal to its own bulk, we conclude, that the mixture neither contains muriatic acid, ſulphuric acid, or ammoniacal gas, but that it contains carbonic acid gas, of which water only abſorbs about its own bulk. To aſcertain this conjecture, introduce ſome ſolution of cauſtic alkali, and the carbonic acid gas will be gradually abſorbed in the courſe of a few hours; it combines with the cauſtic alkali or potaſh, and the remaining gas is left almoſt perfectly free from any ſenſible reſiduum of carbonic acid gas.

After each experiment of this kind, we muſt carefully mark the height at which the mercury ſtands within the jar, by ſlips of paper paſted on, and varniſhed over when dry, that they may not be waſhed off when placed in the water apparatus.

paratus. It is likewiſe neceſſary to regiſter the difference between the ſurface of the mercury in the ciſtern and that in the jar, and the height of the barometer and thermometer, at the end of each experiment.

When all the gas or gaſſes abſorbable by water and potaſh are abſorbed, water is admitted into the jar to diſplace the mercury; and, as is deſcribed in the preceding ſection, the mercury in the ciſtern is to be covered by one or two inches of water. After this, the jar is to be tranſported by means of the flat diſh BC, Pl. V. Fig. 9. into the water apparatus; and the quantity of gas remaining is to be aſcertained by changing it into a graduated jar. After this, ſmall trials of it are to be made by experiments in little jars, to aſcertain nearly the nature of the gas in queſtion. For inſtance, into a ſmall jar full of the gas, Fig. 8. Pl. V. a lighted taper is introduced; if the taper is not immediately extinguiſhed, we conclude the gas to contain oxygen gas; and, in proportion to the brightneſs of the flame, we may judge if it contain leſs or more oxygen gas than atmoſpheric air contains. If, on the contrary, the taper be inſtantly extinguiſhed, we have ſtrong reaſon to preſume that the reſiduum is chiefly compoſed of azotic gas. If, upon the approach of the taper, the gas takes fire and burns quietly at the ſurface with a white flame, we conclude it to be

pure

pure hydrogen gas; if this flame is blue, we judge it conſiſts of carbonated hydrogen gas; and, if it takes fire with a ſudden deflagration, that it is a mixture of oxygen and hydrogen gas. If, again, upon mixing a portion of the reſiduum with oxygen gas, red fumes are produced, we conclude that it contains nitrous gas.

Theſe preliminary trials give ſome general knowledge of the properties of the gas, and nature of the mixture, but are not ſufficient to determine the proportions and quantities of the ſeveral gaſſes of which it is compoſed. For this purpoſe all the methods of analyſis muſt be employed; and, to direct theſe properly, it is of great uſe to have a previous approximation by the above methods. Suppoſe, for inſtance, we know that the reſiduum conſiſts of oxygen and azotic gas mixed together, put a determinate quantity, 100 parts, into a graduated tube of ten or twelve lines diameter, introduce a ſolution of ſulphuret of potaſh in contact with the gas, and leave them together for ſome days; the ſulphuret abſorbs the whole oxygen gas, and leaves the azotic gas pure.

If it is known to contain hydrogen gas, a determinate quantity is introduced into Volta's eudiometer alongſt with a known proportion of hydrogen gas; theſe are deflagrated together by means of the electrical ſpark; freſh portions of oxygen gas are ſucceſſively added, till no farther

ther deflagration takes place, and till the greateſt poſſible diminution is produced. By this proceſs water is formed, which is immediately abſorbed by the water of the apparatus; but, if the hydrogen gas contain charcoal, carbonic acid is formed at the ſame time, which is not abſorbed ſo quickly; the quantity of this is readily aſcertained by aſſiſting its abſorption, by means of agitation. If the reſiduum contains nitrous gas, by adding oxygen gas, with which it combines into nitric acid, we can very nearly aſcertain its quantity, from the diminution produced by this mixture.

I confine myſelf to theſe general examples, which are ſufficient to give an idea of this kind of operations; a whole volume would not ſerve to explain every poſſible caſe. It is neceſſary to become familiar with the analyſis of gaſſes by long experience; we muſt even acknowledge that they moſtly poſſeſs ſuch powerful affinities to each other, that we are not always certain of having ſeparated them completely. In theſe caſes, we muſt vary our experiments in every poſſible point of view, add new agents to the combination, and keep out others, and continue our trials, till we are certain of the truth and exactitude of our concluſions.

SECT. V.

Of the neceſſary corrections upon the volume of the Gaſſes, according to the preſſure of the Atmoſphere.

All elaſtic fluids are compreſſible or condenſible in proportion to the weight with which they are loaded: Perhaps this law, which is aſcertained by general experience, may ſuffer ſome irregularity when theſe fluids are under a degree of condenſation almoſt ſufficient to reduce them to the liquid ſtate, or when either in a ſtate of extreme rarefaction or condenſation; but we ſeldom approach either of theſe limits with moſt of the gaſſes which we ſubmit to our experiments. I underſtand this propoſition of gaſſes being compreſſible, in proportion to their ſuperincumbent weights, as follows:

A barometer, which is an inſtrument generally known, is, properly ſpeaking, a ſpecies of ſyphon, ABCD, Pl. XII. Fig. 16. whoſe leg AB is filled with mercury, whilſt the leg CD is full of air. If we ſuppoſe the branch CD indefinitely continued till it equals the height of our atmoſphere, we can readily conceive that the barometer is, in reality, a ſort of balance, in which

a

a column of mercury ſtands in equilibrium with a column of air of the ſame weight. But it is unneceſſary to prolongate the branch CD to ſuch a height, as it is evident that the barometer being immerſed in air, the column of mercury AB will be equally in equilibrium with a column of air of the ſame diameter, though the leg CD be cut off at C, and the part CD be taken away altogether.

The medium height of mercury in equilibrium with the weight of a column of air, from the higheſt part of the atmoſphere to the ſurface of the earth is about twenty-eight French inches in the lower parts of the city of Paris; or, in other words, the air at the ſurface of the earth at Paris is uſually preſſed upon by a weight equal to that of a column of mercury twenty-eight inches in height. I muſt be underſtood in this way in the ſeveral parts of this publication when talking of the different gaſſes, as, for inſtance, when the cubical foot of oxygen gas is ſaid to weigh 1 *oz.* 4 *gros*, under 28 inches preſſure. The height of this column of mercury, ſupported by the preſſure of the air, diminiſhes in proportion as we are elevated above the ſurface of the earth, or rather above the level of the ſea, becauſe the mercury can only form an equilibrium with the column of air which is above it, and is not in the ſmalleſt degree affected by the air which is below its level.

In what ratio does the mercury in the barometer deſcend in proportion to its elevation? or, what is the ſame thing, according to what law or ratio do the ſeveral ſtrata of the atmoſphere decreaſe in denſity? This queſtion, which has exerciſed the ingenuity of natural philoſophers during laſt century, is conſiderably elucidated by the following experiment.

If we take the glaſs ſyphon ABCDE, Pl. XII. Fig. 17. ſhut at E, and open at A, and introduce a few drops of mercury, ſo as to intercept the communication of air between the leg AB and the leg BE, it is evident that the air contained in BCDE is preſſed upon, in common with the whole ſurrounding air, by a weight or column of air equal to 28 inches of mercury. But, if we pour 28 inches of mercury into the leg AB, it is plain the air in the branch BCDE will now be preſſed upon by a weight equal to twice 28 inches of mercury, or twice the weight of the atmoſphere; and experience ſhows, that, in this caſe, the included air, inſtead of filling the tube from B to E, only occupies from C to E, or exactly one half of the ſpace it filled before. If to this firſt column of mercury we add two other portions of 28 inches each, in the branch AB, the air in the branch BCDE will be preſſed upon by four times the weight of the atmoſphere,

atmoſphere, or four times the weight of 28 inches of mercury, and it will then only fill the ſpace from D to E, or exactly one quarter of the ſpace it occupied at the commencement of the experiment. From theſe experiments, which may be infinitely varied, has been deduced as a general law of nature, which ſeems applicable to all permanently elaſtic fluids, that they diminiſh in volume in proportion to the weights with which they are preſſed upon; or, in other words, "*the volume of all elaſtic fluids is in the* "*inverſe ratio of the weight by which they are* "*compreſſed.*"

The experiments which have been made for meaſuring the heights of mountains by means of the barometer, confirm the truth of theſe deductions; and, even ſuppoſing them in ſome degree inaccurate, theſe differences are ſo extremely ſmall, that they may be reckoned as nullities in chemical experiments. When this law of the compreſſion of elaſtic fluids is once well underſtood, it becomes eaſily applicable to the corrections neceſſary in pneumato-chemical experiments upon the volume of gas, in relation to its preſſure. Theſe corrections are of two kinds, the one relative to the variations of the barometer, and the other for the column of water or mercury contained in the jars. I ſhall endeavour to explain theſe by examples, beginning with the moſt ſimple caſe.

Suppoſe

Suppoſe that 100 cubical inches of oxygen gas are obtained at 10° (54.5°) of the thermometer, and at 28 inches 6 lines of the barometer, it is required to know what volume the 100 cubical inches of gas would occupy, under the preſſure of 28 inches *, and what is the exact weight of the 100 inches of oxygen gas? Let the unknown volume, or the number of inches this gas would occupy at 28 inches of the barometer, be expreſſed by x; and, ſince the volumes are in the inverſe ratio of their ſuperincumbent weights, we have the following ſtatement: 100 cubical inches is to x inverſely as 28.5 inches of preſſure is to 28.0 inches; or directly $28 : 28.5 :: 100 : x = 101.786$ — cubical inches, at 28 inches barometrical preſſure; that is to ſay, the ſame gas or air which at 28.5 inches of the barometer occupies 100 cubical inches of volume, will occupy 101.786 cubical inches when the barometer is at 28 inches. It is equally eaſy to calculate the weight of this gas, occupying 100 cubical inches, under 28.5 inches of barometrical preſſure; for, as it correſponds

---

* According to the proportion of 114 to 107, given between the French and Engliſh foot, 28 inches of the French barometer are equal to 29.83 inches of the Engliſh. Directions will be found in the appendix for converting all the French weights and meaſures uſed in this work into correſponding Engliſh denominations.

reſponds to 101.786 cubical inches at the preſſure of 28, and as, at this preſſure, and at 10° (54.5°) of temperature, each cubical inch of oxygen gas weighs half a grain, it follows, that 100 cubical inches, under 28.5 barometrical preſſure, muſt weigh 50.893 grains. This concluſion might have been formed more directly, as, ſince the volume of elaſtic fluids is in the inverſe ratio of their compreſſion, their weights muſt be in the direct ratio of the ſame compreſſion: Hence, ſince 100 cubical inches weigh 50 grains, under the preſſure of 28 inches, we have the following ſtatement to determine the weight of 100 cubical inches of the ſame gas as 28.5 barometrical preſſure, 28 : 50 : : 28.5 : x, the unknown quantity, = 50.893.

The following caſe is more complicated: Suppoſe the jar A, Pl. XII. Fig. 18. to contain a quantity of gas in its upper part ACD, the reſt of the jar below CD being full of mercury, and the whole ſtanding in the mercurial baſon or reſervoir GHIK, filled with mercury up to EF, and that the difference between the ſurface CD of the mercury in the jar, and EF, that in the ciſtern, is ſix inches, while the barometer ſtands at 27.5 inches. It is evident from theſe data, that the air contained in ACD is preſſed upon by the weight of the atmoſphere, diminiſhed by the weight of the column of mercury CE, or by 27.5 — 6 = 21.5 inches of barometrical preſſure.

preſſure. This air is therefore leſs compreſſed than the atmoſphere at the mean height of the barometer, and conſequently occupies more ſpace than it would occupy at the mean preſſure, the difference being exactly proportional to the difference between the compreſſing weights. If, then, upon meaſuring the ſpace ACD, it is found to be 120 cubical inches, it muſt be reduced to the volume which it would occupy under the mean preſſure of 28 inches. This is done by the following ſtatement: 120 : x, the unknown volume, : : 21.5 : 28 inverſely; this gives $x = \frac{120 \times 21.5}{28} = 92.143$ cubical inches.

In theſe calculations we may either reduce the height of the mercury in the barometer, and the difference of level in the jar and baſon, into lines or decimal fractions of the inch; but I prefer the latter, as it is more readily calculated. As, in theſe operations, which frequently recur, it is of great uſe to have means of abbreviation, I have given a table in the appendix for reducing lines and fractions of lines into decimal fractions of the inch.

In experiments performed in the water-apparatus, we muſt make ſimilar corrections to procure rigorouſly exact reſults, by taking into account, and making allowances for the difference of height of the water within the jar above the ſurface of the water in the ciſtern. But, as the preſſure

preſſure of the atmoſphere is expreſſed in inches and lines of the mercurial barometer, and, as homogeneous quantities only can be calculated together, we muſt reduce the obſerved inches and lines of water into correſpondent heights of the mercury. I have given a table in the appendix for this converſion, upon the ſuppoſition that mercury is 13.5681 times heavier than water.

SECT. VI.

Of Corrections relative to the Degrees of the Thermometer.

In aſcertaining the weight of gaſſes, beſides reducing them to a mean of barometrical preſſure, as directed in the preceding ſection, we muſt likewiſe reduce them to a ſtandard thermometrical temperature; becauſe, all elaſtic fluids being expanded by heat, and condenſed by cold, their weight in any determinate volume is thereby liable to conſiderable alterations. As the temperature of 10° (54.5°) is a medium between the heat of ſummer and the cold of winter, being the temperature of ſubterraneous places, and that which is moſt eaſily approached to at all ſeaſons, I have choſen that degree as a mean to which I reduce air or gas in this ſpecies of calculation.

Mr

Mr de Luc found that atmoſpheric air was increaſed $\frac{1}{215}$ part of its bulk, by each degree of a mercurial thermometer, divided into 81 degrees, between the freezing and boiling points; this gives $\frac{1}{211}$ part for each degree of Reaumur's thermometer, which is divided into 80 degrees between theſe two points. The experiments of Mr Monge ſeem to make this dilatation leſs for hydrogen gas, which he thinks is only dilated $\frac{1}{180}$. We have not any exact experiments hitherto publiſhed reſpecting the ratio of dilatation of the other gaſſes; but, from the trials which have been made, their dilatation ſeems to differ little from that of atmoſpheric air. Hence I may take for granted, till farther experiments give us better information upon this ſubject, that atmoſpherical air is dilated $\frac{1}{210}$ part, and hydrogen gas $\frac{1}{190}$ part for each degree of the thermometer; but, as there is ſtill great uncertainty upon this point, we ought always to operate in a temperature as near as poſſible to the ſtandard of 10°, (54.5°) by this means any errors in correcting the weight or volume of gaſſes by reducing them to the common ſtandard, will become of little moment.

The calculation for this correction is extremely eaſy. Divide the obſerved volume of air by 210, and multiply the quotient by the degrees of temperature above or below 10° (54.5°).

(54.5°). This correction is negative when the actual temperature is above the ſtandard, and poſitive when below. By the uſe of logarithmical tables this calculation is much facilitated *.

SECT. VII.

Example for calculating the Corrections relative to the Variations of Preſſure and Temperature.

CASE.

In the jar A, Pl. IV. Fig. 3. ſtanding in a water apparatus, is contained 353 cubical inches of air; the ſurface of the water within the jar at EF is 4½ inches above the water in the ciſtern, the barometer is at 27 inches 9½ lines, and the thermometer at 15° (65.75°). Having burnt a quantity of phoſphorus in the air, by which concrete phoſphoric acid is produced, the air after the combuſtion occupies 295 cubical inches,

---

* When Fahrenheit's thermometer is employed, the dilatation by each degree muſt be ſmaller, in the proportion of 1 to 2.25, becauſe each degree of Reaumur's ſcale contains 2.25 degrees of Fahrenheit; hence we muſt divide by 472.5, and finiſh the reſt of the calculation as above.—E.

inches, the water within the jar ſtands 7 inches above that in the ciſtern, the barometer is at 27 inches 9¼ lines, and the thermometer at 16° (68°). It is required from theſe data to determine the actual volume of air before and after combuſtion, and the quantity abſorbed during the proceſs.

Calculation before Combuſtion.

The air in the jar before combuſtion was 353 cubical inches, but it was only under a barometrical preſſure of 27 inches 9½ lines; which, reduced to decimal fractions by Tab. I. of the Appendix, gives 27.79167 inches; and from this we muſt deduct the difference of 4½ inches of water, which, by Tab. II. correſponds to 0.33166 inches of the barometer; hence the real preſſure of the air in the jar is 27.46001. As the volume of elaſtic fluids diminiſh in the inverſe ratio of the compreſſing weights, we have the following ſtatement to reduce the 353 inches to the volume the air would occupy at 28 inches barometrical preſſure.

353 : x, the unknown volume, :: 27.46001 : 28. Hence, $x = \frac{353 \times 27.46001}{28} = 346.192$ cubical inches, which is the volume the ſame quantity of air would have occupied at 28 inches of the barometer.

The

The 210th part of this corrected volume is 1.65, which, for the five degrees of temperature above the ſtandard gives 8.255 cubical inches; and, as this correction is ſubſtractive, the real corrected volume of the air before combuſtion is 337.942 inches.

Calculation after Combuſtion.

By a ſimilar calculation upon the volume of air after combuſtion, we find its barometrical preſſure $27.77083 - 0.51593 = 27.25490$. Hence, to have the volume of air under the preſſure of 28 inches, $295 : x :: 27.77083 : 28$ inverſely; or, $x = \frac{295 \times 27.25490}{28} = 287.150$. The 210th part of this corrected volume is 1.368, which, multiplied by 6 degrees of thermometrical difference, gives the ſubtractive correction for temperature 8.208, leaving the actual corrected volume of air after combuſtion 278.942 inches.

Reſult.

The corrected volume before combuſtion	337.942
Ditto remaining after combuſtion .	278.942
Volume abſorbed during combuſtion	59.000.

SECT. VIII.

Method of determining the Abſolute Gravity of the different Gaſſes.

Take a large balloon A, Pl.V. Fig. 10. capable of holding 17 or 18 pints, or about half a cubical foot, having the braſs cap *bcde* ſtrongly cemented to its neck, and to which the tube and ſtop-cock *fg* is fixed by a tight ſcrew. This apparatus is connected by the double ſcrew repreſented ſeparately at Fig. 12. to the jar BCD, Fig. 10. which muſt be ſome pints larger in dimenſions than the balloon. This jar is open at top, and is furniſhed with the braſs cap *h i*, and ſtop-cock *l m*. One of theſe ſtop-cocks is repreſented ſeparately at Fig. 11.

We firſt determine the exact capacity of the balloon by filling it with water, and weighing it both full and empty. When emptied of water, it is dried with a cloth introduced through its neck *d e*, and the laſt remains of moiſture are removed by exhauſting it once or twice in an air-pump.

When the weight of any gas is to be aſcertained, this apparatus is uſed as follows: Fix the balloon A to the plate of an air-pump by means of the ſcrew of the ſtop-cock *f g*, which is left

left open; the balloon is to be exhauſted as completely as poſſible, obſerving carefully the degree of exhauſtion by means of the barometer attached to the air-pump. When the vacuum is formed, the ſtop-cock *f g* is ſhut, and the weight of the balloon determined with the moſt ſcrupulous exactitude. It is then fixed to the jar BCD, which we ſuppoſe placed in water in the ſhelf of the pneumato-chemical apparatus Fig. 1.; the jar is to be filled with the gas we mean to weigh, and then, by opening the ſtop-cocks *f g* and *l m*, the gas aſcends into the balloon, whilſt the water of the ciſtern riſes at the ſame time into the jar. To avoid very troubleſome corrections, it is neceſſary, during this firſt part of the operation, to ſink the jar in the ciſtern till the ſurfaces of the water within the jar and without exactly correſpond. The ſtop-cocks are again ſhut, and the balloon being unſcrewed from its connection with the jar, is to be carefully weighed; the difference between this weight and that of the exhauſted balloon is the preciſe weight of the air or gas contained in the balloon. Multiply this weight by 1728, the number of cubical inches in a cubical foot, and divide the product by the number of cubical inches contained in the balloon, the quotient is the weight of a cubical foot of the gas or air ſubmitted to experiment.

Exact account muſt be kept of the barometrical height and temperature of the thermometer during the above experiment; and from theſe the reſulting weight of a cubical foot is eaſily corrected to the ſtandard of 28 inches and 10°, as directed in the preceding ſection. The ſmall portion of air remaining in the balloon after forming the vacuum muſt likewiſe be attended to, which is eaſily determined by the barometer attached to the air-pump. If that barometer, for inſtance, remains at the hundredth part of the height it ſtood at before the vacuum was formed, we conclude that one hundredth part of the air originally contained remained in the balloon, and conſequently that only $\frac{99}{100}$ of gas was introduced from the jar into the balloon.

CHAP. III.

Deſcription of the Calorimeter, or Apparatus for meaſuring Caloric.

THE calorimeter, or apparatus for meaſuring the relative quantities of heat contained in bodies, was deſcribed by Mr de la Place and me in the Memoirs of the Academy for 1780, p. 355. and from that Eſſay the materials of this chapter are extracted.

If, after having cooled any body to the freezing point, it be expoſed in an atmoſphere of 25° (88.25°), the body will gradually become heated, from the ſurface inwards, till at laſt it acquire the ſame temperature with the ſurrounding air. But, if a piece of ice be placed in the ſame ſituation, the circumſtances are quite different; it does not approach in the ſmalleſt degree towards the temperature of the circumambient air, but remains conſtantly at Zero (32°), or the temperature of melting ice, till the laſt portion of ice be completely melted.

This phenomenon is readily explained; as, to melt ice, or reduce it to water, it requires to be combined with a certain portion of caloric; the

the whole caloric attracted from the ſurrounding bodies, is arreſted or fixed at the ſurface or external layer of ice which it is employed to diſſolve, and combines with it to form water; the next quantity of caloric combines with the ſecond layer to diſſolve it into water, and ſo on ſucceſſively till the whole ice be diſſolved or converted into water by combination with caloric, the very laſt atom ſtill remaining at its former temperature, becauſe the caloric has never penetrated ſo far as long as any intermediate ice remained to melt.

Upon theſe principles, if we conceive a hollow ſphere of ice at the temperature of Zero (32°) placed in an atmoſphere 10° (54.5°), and containing a ſubſtance at any degree of temperature above freezing, it follows, 1ſt, That the heat of the external atmoſphere cannot penetrate into the internal hollow of the ſphere of ice; 2dly, That the heat of the body placed in the hollow of the ſphere cannot penetrate outwards beyond it, but will be ſtopped at the internal ſurface, and continually employed to melt ſucceſſive layers of ice, until the temperature of the body be reduced to *Zero* (32°), by having all its ſuperabundant caloric above that temperature carried off by the ice. If the whole water, formed within the ſphere of ice during the reduction of the temperature of the included body to *Zero*, be carefully collected, the weight of of the water will be exactly proportional to the quantity of caloric loſt by the body in paſſing from its original temperature to that of melting ice; for it is evident that a double quantity of caloric would have melted twice the quantity of ice; hence the quantity of ice melted is a very exact meaſure of the quantity of caloric employed to produce that effect, and conſequently of the quantity loſt by the only ſubſtance that could poſſibly have ſupplied it.

I have made this ſuppoſition of what would take place in a hollow ſphere of ice, for the purpoſe of more readily explaining the method uſed in this ſpecies of experiment, which was firſt conceived by Mr de la Place. It would be difficult to procure ſuch ſpheres of ice, and inconvenient to make uſe of them when got; but, by means of the following apparatus, we have remedied that defect. I acknowledge the name of Calorimeter, which I have given it, as derived partly from Greek and partly from Latin, is in ſome degree open to criticiſm; but, in matters of ſcience, a ſlight deviation from ſtrict etymology, for the ſake of giving diſtinctneſs of idea, is excuſable; and I could not derive the name entirely from Greek without approaching too near to the names of known inſtruments employed for other purpoſes.

The calorimeter is repreſented in Pl. VI. It is ſhown in perſpective at Fig. 1. and its interior ſtructure is engraved in Fig. 2. and 3.; the former being a horizontal, and the latter a perpendicular ſection. Its capacity or cavity is divided into three parts, which, for better diſtinction, I ſhall name the interior, middle, and external cavities. The interior cavity *f f f f*, Fig. 4. into which the ſubſtances ſubmitted to experiment are put, is compoſed of a grating or cage of iron wire, ſupported by ſeveral iron bars; its opening or mouth LM, is covered by the lid HG, of the ſame materials. The middle cavity *b b b b*, Fig. 2. and 3. is intended to contain the ice which ſurrounds the interior cavity, and which is to be melted by the caloric of the ſubſtance employed in the experiment. The ice is ſupported by the grate *m m* at the bottom of the cavity, under which is placed the ſieve *n n*. Theſe two are repreſented ſeparately in Fig. 5. and 6.

In proportion as the ice contained in the middle cavity is melted, by the caloric diſengaged from the body placed in the interior cavity, the water runs through the grate and ſieve, and falls through the conical funnel *c c d*, Fig. 3. and tube *x y*, into the receiver F, Fig. 1. This water may be retained or let out at pleaſure, by means of the ſtop-cock *u*. The external cavity *a a a a*, Fig. 2. and 3. is filled with ice, to prevent any effect upon the ice in the middle cavity from the heat of the ſurrounding air, and the

the water produced from it is carried off through the pipe ST, which ſhuts by means of the ſtop-cock *r*. The whole machine is covered by the lid FF, Fig. 7. made of tin painted with oil colour, to prevent ruſt.

When this machine is to be employed, the middle cavity *bbbb*, Fig. 2. and 3. the lid GH, Fig. 4. of the interior cavity, the external cavity *aaaa*, Fig. 2. and 3. and the general lid FF, Fig. 7. are all filled with pounded ice, well rammed, ſo that no void ſpaces remain, and the ice of the middle cavity is allowed to drain. The machine is then opened, and the ſubſtance ſubmitted to experiment being placed in the interior cavity, it is inſtantly cloſed. After waiting till the included body is completely cooled to the freezing point, and the whole melted ice has drained from the middle cavity, the water collected in the veſſel F, Fig. 1. is accurately weighed. The weight of the water produced during the experiment is an exact meaſure of the caloric diſengaged during the cooling of the included body, as this ſubſtance is evidently in a ſimilar ſituation with the one formerly mentioned as included in a hollow ſphere of ice; the whole caloric diſengaged is ſtopped by the ice in the middle cavity, and that ice is preſerved from being affected by any other heat by means of the ice contained in the general lid, Fig. 7. and in the external cavity. Experiments

of

of this kind laſt from fifteen to twenty hours; they are ſometimes accelerated by covering up the ſubſtance in the interior cavity with well drained ice, which haſtens its cooling.

The ſubſtances to be operated upon are placed in the thin iron bucket, Fig. 8. the cover of which has an opening fitted with a cork, into which a ſmall thermometer is fixed. When we uſe acids, or other fluids capable of injuring the metal of the inſtruments, they are contained in the matras, Fig. 10. which has a ſimilar thermometer in a cork fitted to its mouth, and which ſtands in the interior cavity upon the ſmall cylindrical ſupport RS, Fig. 10.

It is abſolutely requiſite that there be no communication between the external and middle cavities of the calorimeter, otherwiſe the ice melted by the influence of the ſurrounding air, in the external cavity, would mix with the water produced from the ice of the middle cavity, which would no longer be a meaſure of the caloric loſt by the ſubſtance ſubmitted to experiment.

When the temperature of the atmoſphere is only a few degrees above the freezing point, its heat can hardly reach the middle cavity, being arreſted by the ice of the cover, Fig. 7. and of the external cavity; but, if the temperature of the air be under the degree of freezing, it might cool the ice contained in the middle cavity, by cauſing

cauſing the ice in the external cavity to fall, in the firſt place, below zero (32°). It is therefore eſſential that this experiment be carried on in a temperature ſomewhat above freezing: Hence, in time of froſt, the calorimeter muſt be kept in an apartment carefully heated. It is likewiſe neceſſary that the ice employed be not under zero (32°); for which purpoſe it muſt be pounded, and ſpread out thin for ſome time, in a place of a higher temperature.

The ice of the interior cavity always retains a certain quantity of water adhering to its ſurface, which may be ſuppoſed to belong to the reſult of the experiment; but as, at the beginning of each experiment, the ice is already ſaturated with as much water as it can contain, if any of the water produced by the caloric ſhould remain attached to the ice, it is evident, that very nearly an equal quantity of what adhered to it before the experiment muſt have run down into the veſſel F in its ſtead; for the inner ſurface of the ice in the middle cavity is very little changed during the experiment.

By any contrivance that could be deviſed, we could not prevent the acceſs of the external air into the interior cavity when the atmoſphere was 9° or 10° (52° or 54°) above zero. The air confined in the cavity being in that caſe ſpecifically heavier than the external air, eſcapes downwards through the pipe *x y*, Fig. 3, and is replaced by the warmer external air, which, giving out its caloric to the ice, becomes heavier, and ſinks in its turn; thus a current of air is formed through the machine, which is the more rapid in proportion as the external air exceeds the internal in temperature. This current of warm air muſt melt a part of the ice, and injure the accuracy of the experiment: We may, in a great degree, guard againſt this ſource of error by keeping the ſtop-cock *u* continually ſhut; but it is better to operate only when the temperature of the external air does not exceed 3°, or at moſt 4°, (39° to 41°); for we have obſerved, that, in this caſe, the melting of the interior ice by the atmoſpheric air is perfectly inſenſible; ſo that we may anſwer for the accuracy of our experiments upon the ſpecific heat of bodies to a fortieth part.

We have cauſed make two of the above deſcribed machines; one, which is intended for ſuch experiments as do not require the interior air to be renewed, is preciſely formed according to the deſcription here given; the other, which anſwers for experiments upon combuſtion, reſpiration, &c. in which freſh quantities of air are indiſpenſibly neceſſary, differs from the former in having two ſmall tubes in the two lids, by which a current of atmoſpheric air may be blown into the interior cavity of the machine.

It

It is extremely eaſy, with this apparatus, to determine the phenomena which occur in operations where caloric is either diſengaged or abſorbed. If we wiſh, for inſtance, to aſcertain the quantity of caloric which is diſengaged from a ſolid body in cooling a certain number of degrees, let its temperature be raiſed to 80° (212°); it is then placed in the interior cavity *ffff*, Fig. 2. and 3. of the calorimeter, and allowed to remain till we are certain that its temperature is reduced to zero (32°); the water produced by melting the ice during its cooling is collected, and carefully weighed; and this weight, divided by the volume of the body ſubmitted to experiment, multiplied into the degrees of temperature which it had above zero at the commencement of the experiment, gives the proportion of what the Engliſh philoſophers call ſpecific heat.

Fluids are contained in proper veſſels, whoſe ſpecific heat has been previouſly aſcertained, and operated upon in the machine in the ſame manner as directed for ſolids, taking care to deduct, from the quantity of water melted during the experiment, the proportion which belongs to the containing veſſel.

If the quantity of caloric diſengaged during the combination of different ſubſtances is to be determined, theſe ſubſtances are to be previouſly reduced to the freezing degree by keeping them

them a ſufficient time ſurrounded with pounded ice; the mixture is then to be made in the inner cavity of the calorimeter, in a proper veſſel likewiſe reduced to zero (32°); and they are kept incloſed till the temperature of the combination has returned to the ſame degree: The quantity of water produced is a meaſure of the caloric diſengaged during the combination.

To determine the quantity of caloric diſengaged during combuſtion, and during animal reſpiration, the combuſtible bodies are burnt, or the animals are made to breathe in the interior cavity, and the water produced is carefully collected. Guinea-pigs, which reſiſt the effects of cold extremely well, are well adapted for this experiment. As the continual renewal of air is abſolutely neceſſary in ſuch experiments, we blow freſh air into the interior cavity of the calorimeter by means of a pipe deſtined for that purpoſe, and allow it to eſcape through another pipe of the ſame kind; and that the heat of this air may not produce errors in the reſults of the experiments, the tube which conveys it into the machine is made to paſs through pounded ice, that it may be reduced to zero (32°) before it arrives at the calorimeter. The air which eſcapes muſt likewiſe be made to paſs through a tube ſurrounded with ice, included in the interior cavity of the machine, and the water which is produced muſt make a part of what is collected,

collected, becauſe the caloric diſengaged from this air is part of the product of the experiment.

It is ſomewhat more difficult to determine the ſpecific caloric contained in the different gaſſes, on account of their ſmall degree of denſity; for, if they are only placed in the calorimeter in veſſels like other fluids, the quantity of ice melted is ſo ſmall, that the reſult of the experiment becomes at beſt very uncertain. For this ſpecies of experiment we have contrived to make the air paſs through two metallic worms, or ſpiral tubes; one of theſe, through which the air paſſes, and becomes heated in its way to the calorimeter, is contained in a veſſel full of boiling water, and the other, through which the air circulates within the calorimeter to diſengage its caloric, is placed in the interior cavity, *ffff*, of that machine. By means of a ſmall thermometer placed at one end of the ſecond worm, the temperature of the air, as it enters the calorimeter, is determined, and its temperature in getting out of the interior cavity is found by another thermometer placed at the other end of the worm. By this contrivance we are enabled to aſcertain the quantity of ice melted by determinate quantities of air or gas, while loſing a certain number of degrees of temperature, and, conſequently, to determine their ſeveral degrees of ſpecific caloric. The ſame apparatus, with ſome particular precautions, may be employed to aſcertain the quantity of caloric diſengaged by the condenſation of the vapours of different liquids.

The various experiments which may be made with the calorimeter do not afford abſolute concluſions, but only give us the meaſure of relative quantities; we have therefore to fix a unit, or ſtandard point, from whence to form a ſcale of the ſeveral reſults. The quantity of caloric neceſſary to melt a pound of ice has been choſen as this unit; and, as it requires a pound of water of the temperature of 60° (167°) to melt a pound of ice, the quantity of caloric expreſſed by our unit or ſtandard point is what raiſes a pound of water from zero (32°) to 60° (167°). When this unit is once determined, we have only to expreſs the quantities of caloric diſengaged from different bodies by cooling a certain number of degrees, in analogous values: The following is an eaſy mode of calculation for this purpoſe, applied to one of our earlieſt experiments.

We took 7 *lib.* 11 *oz.* 2 *gros* 36 *grs.* of plate-iron, cut into narrow ſlips, and rolled up, or expreſſing the quantity in decimals, 7.7070319. Theſe, being heated in a bath of boiling water to about 78° (207.5°), were quickly introduced into the interior cavity of the calorimeter: At the

the end of eleven hours, when the whole quantity of water melted from the ice had thoroughly drained off, we found that 1.109795 pounds of ice were melted. Hence, the caloric diſengaged from the iron by cooling 78° (175.5°) having melted 1.109795 pounds of ice, how much would have been melted by cooling 60° (135°)? This queſtion gives the following ſtatement in direct proportion, $78:1.109795::60:x = 0.85369$. Dividing this quantity by the weight of the whole iron employed, viz. 7.7070319, the quotient 0.110770 is the quantity of ice which would have been melted by one pound of iron whilſt cooling through 60° (135°) of temperature.

Fluid ſubſtances, ſuch as ſulphuric and nitric acids, &c. are contained in a matras, Pl. VI. Fig. 9. having a thermometer adapted to the cork, with its bulb immerſed in the liquid. The matras is placed in a bath of boiling water, and when, from the thermometer, we judge the liquid is raiſed to a proper temperature, the matras is placed in the calorimeter. The calculation of the products, to determine the ſpecific caloric of theſe fluids, is made as above directed, taking care to deduct from the water obtained the quantity which would have been produced by the matras alone, which muſt be aſcertained by a previous experiment. The

table

table of the reſults obtained by theſe experiments is omitted, becauſe not yet ſufficiently complete, different circumſtances having occaſioned the ſeries to be interrupted; it is not, however, loſt ſight of; and we are leſs or more employed upon the ſubject every winter.

CHAP. IV.

Of Mechanical Operations for Diviſion of Bodies.

SECT. I.

Of Trituration, Levigation, and Pulverization.

THESE are, properly ſpeaking, only preliminary mechanical operations for dividing and ſeparating the particles of bodies, and reducing them into very fine powder. Theſe operations can never reduce ſubſtances into their primary, or elementary and ultimate particles; they do not even deſtroy the aggregation of bodies; for every particle, after the moſt accurate trituration, forms a ſmall whole, reſembling the original maſs from which it was divided. The real chemical operations, on the contrary, ſuch as ſolution, deſtroy the aggregation of bodies, and ſeparate their conſtituent and integrant particles from each other.

Brittle

Brittle ſubſtances are reduced to powder by means of peſtles and mortars. Theſe are of braſs or iron, Pl. I. Fig. 1.; of marble or granite, Fig. 2.; of lignum vitae, Fig. 3.; of glaſs, Fig. 4.; of agate, Fig. 5.; or of porcellain, Fig. 6. The peſtles for each of theſe are repreſented in the plate, immediately below the mortars to which they reſpectively belong, and are made of hammered iron or braſs, of wood, glaſs, porcellain, marble, granite, or agate, according to the nature of the ſubſtances they are intended to triturate. In every laboratory, it is requiſite to have an aſſortment of theſe utenſils, of various ſizes and kinds: Thoſe of porcellain and glaſs can only be uſed for rubbing ſubſtances to powder, by a dexterous uſe of the peſtle round the ſides of the mortar, as it would be eaſily broken by reiterated blows of the peſtle.

The bottom of mortars ought to be in the form of a hollow ſphere, and their ſides ſhould have ſuch a degree of inclination as to make the ſubſtances they contain fall back to the bottom when the peſtle is lifted, but not ſo perpendicular as to collect them too much together, otherwiſe too large a quantity would get below the peſtle, and prevent its operation. For this reaſon, likewiſe, too large a quantity of the ſubſtance to be powdered ought not to be put into the mortar at one time; and we muſt from time to time get rid of the particles already reduced to powder, by means of ſieves to be afterwards deſcribed.

The moſt uſual method of levigation is by means of a flat table ABCD, Pl. 1. Fig. 7. of porphyry, or other ſtone of ſimilar hardneſs, upon which the ſubſtance to be reduced to powder is ſpread, and is then bruiſed and rubbed by a muller M, of the ſame hard materials, the bottom of which is made a ſmall portion of a large ſphere; and, as the muller tends continually to drive the ſubſtances towards the ſides of the table, a thin flexible knife, or ſpatula of iron, horn, wood, or ivory, is uſed for bringing them back to the middle of the ſtone.

In large works, this operation is performed by means of large rollers of hard ſtone, which turn upon each other, either horizontally, in the way of corn-mills, or by one vertical roller turning upon a flat ſtone. In the above operations, it is often requiſite to moiſten the ſubſtances a little, to prevent the fine powder from flying off.

There are many bodies which cannot be reduced to powder by any of the foregoing methods; ſuch are fibrous ſubſtances, as woods; ſuch as are tough and elaſtic, as the horns of animals, elaſtic gum, &c. and the malleable metals which flatten under the peſtle, inſtead of being reduced to powder. For reducing the woods to powder, raſps, as Pl. 1. Fig. 8. are employed; files of a finer kind are uſed for horn, and ſtill finer, Pl. 1. Fig. 9. and 10. for metals.

Some of the metals, though not brittle enough to powder under the peſtle, are too ſoft to be filed, as they clog the file, and prevent its operation. Zinc is one of theſe, but it may be powdered when hot in a heated iron mortar, or it may be rendered brittle, by alloying it with a ſmall quantity of mercury. One or other of theſe methods is uſed by fire-work makers for producing a blue flame by means of zinc. Metals may be reduced into grains, by pouring them when melted into water, which ſerves very well when they are not wanted in fine powder.

Fruits, potatoes, &c. of a pulpy and fibrous nature may be reduced to pulp by means of the grater, Pl. 1. Fig. 11.

The choice of the different ſubſtances of which theſe inſtruments are made is a matter of importance; braſs or copper are unfit for operations upon ſubſtances to be uſed as food or in pharmacy; and marble or metallic inſtruments muſt not be uſed for acid ſubſtances; hence mortars of very hard wood, and thoſe of porcelain, granite, or glaſs, are of great utility in many operations.

SECT. II.

Of Sifting and Waſhing Powdered Subſtances.

None of the mechanical operations employed for reducing bodies to powder is capable of producing it of an equal degree of fineneſs throughout; the powder obtained by the longeſt and moſt accurate trituration being ſtill an aſſemblage of particles of various ſizes. The coarſer of theſe are removed, ſo as only to leave the finer and more homogeneous particles by means of ſieves, Pl. I. Fig. 12. 13. 14. 15. of different fineneſſes, adapted to the particular purpoſes they are intended for; all the powdered matter which is larger than the inteſtices of the ſieve remains behind, and is again ſubmitted to the peſtle, while the finer paſs through. The ſieve Fig. 12. is made of hair-cloth, or of ſilk-gauze; and the one repreſented Fig. 13. is of parchment pierced with round holes of a proper ſize; this latter is employed in the manufacture of gun-powder. When very ſubtile or valuable materials are to be ſifted, which are eaſily diſperſed, or when the finer parts of the powder may be hurtful, a compound ſieve, Fig. 15. is made uſe of, which conſiſts of the ſieve ABCD, with a lid EF, and receiver GH; theſe three parts

parts are repreſented as joined together for uſe, Fig. 14.

There is a method of procuring powders of an uniform fineneſs, conſiderably more accurate than the ſieve; but it can only be uſed with ſuch ſubſtances as are not acted upon by water. The powdered ſubſtance is mixed and agitated with water, or other convenient fluid; the liquor is allowed to ſettle for a few moments, and is then decanted off; the coarſeſt powder remains at the bottom of the veſſel, and the finer paſſes over with the liquid. By repeated decantations in this manner, various ſediments are obtained of different degrees of fineneſs; the laſt ſediment, or that which remains longeſt ſuſpended in the liquor, being the fineſt. This proceſs may likewiſe be uſed with advantage for ſeparating ſubſtances of different degrees of ſpecific gravity, though of the ſame fineneſs; this laſt is chiefly employed in mining, for ſeparating the heavier metallic ores from the lighter earthy matters with which they are mixed.

In chemical laboratories, pans and jugs of glaſs or earthen ware are employed for this operation; ſometimes, for decanting the liquor without diſturbing the ſediment, the glaſs ſyphon ABCHI, Pl. II. Fig. 11. is uſed, which may be ſupported by means of the perforated board DE, at the proper depth in the veſſel FG, to draw off all the liquor required into the

receiver

receiver LM. The principles and application of this uſeful inſtrument are ſo well known as to need no explanation.

SECT. III.

Of Filtration.

A filtre is a ſpecies of very fine ſieve, which is permeable to the particles of fluids, but through which the particles of the fineſt powdered ſolids are incapable of paſſing; hence its uſe in ſeparating fine powders from ſuſpenſion in fluids. In pharmacy, very cloſe and fine woollen cloths are chiefly uſed for this operation; theſe are commonly formed in a conical ſhape, Pl. II. Fig. 2. which has the advantage of uniting all the liquor which drains through into a point A, where it may be readily collected in a narrow mouthed veſſel. In large pharmaceutical laboratories, this filtring bag is ſtreached upon a wooden ſtand, Pl. II. Fig. 1.

For the purpoſes of chemiſtry, as it is requiſite to have the filtres perfectly clean, unſized paper is ſubſtituted inſtead of cloth or flannel; through this ſubſtance, no ſolid body, however finely it be powdered, can penetrate, and fluids percolate through it with the greateſt readineſs.

As paper breaks eaſily when wet, various methods of ſupporting it are uſed according to circumſtances. When a large quantity of fluid is to be filtrated, the paper is ſupported by the frame of wood, Pl. II. Fig. 3. ABCD, having a piece of coarſe cloth ſtretched over it, by means of iron-hooks. This cloth muſt be well cleaned each time it is uſed, or even new cloth muſt be employed, if there is reaſon to ſuſpect its being impregnated with any thing which can injure the ſubſequent operations. In ordinary operations, where moderate quantities of fluid are to be filtrated, different kinds of glaſs funnels are uſed for ſupporting the paper, as repreſented Pl. II. Fig. 5. 6. and 7. When ſeveral filtrations muſt be carried on at once, the board or ſhelf AB, Fig. 9. ſupported upon ſtands C and D, and pierced with round holes, is very convenient for containing the funnels.

Some liquors are ſo thick and clammy, as not to be able to penetrate through paper without ſome previous preparation, ſuch as clarification by means of white of eggs, which being mixed with the liquor, coagulates when brought to boil, and, entangling the greater part of the impurities of the liquor, riſes with them to the ſurface in the ſtate of ſcum. Spiritous liquors may be clarified in the ſame manner by means of iſinglaſs diſſolved in water, which coagulates by by the action of the alkohol without the aſſiſtance of heat.

As moſt of the acids are produced by diſtillation, and are conſequently clear, we have rarely any occaſion to filtrate them; but if, at any time, concentrated acids require this operation, it is impoſſible to employ paper, which would be corroded and deſtroyed by the acid. For this purpoſe, pounded glaſs, or rather quartz or rock criſtal, broke in pieces and groſsly powdered, anſwers very well; a few of the larger pieces are put in the neck of the funnel; theſe are covered with the ſmaller pieces, the finer powder is placed over all, and the acid is poured on at top. For the ordinary purpoſes of ſociety, river-water is frequently filtrated by means of clean waſhed ſand, to ſeparate its impurities.

SECT. IV.

Of Decantation.

This operation is often ſubſtituted inſtead of filtration for ſeparating ſolid particles which are diffuſed through liquors. Theſe are allowed to ſettle in conical veſſels, ABCDE, Pl. II. Fig. 10. the diffuſed matters gradually ſubſide, and the clear

clear fluid is gently poured off. If the ſediment be extremely light, and apt to mix again with the fluid by the ſlighteſt motion, the ſyphon, Fig. 11. is uſed, inſtead of decantation, for drawing off the clear fluid.

In experiments, where the weight of the precipitate muſt be rigorouſly aſcertained, decantation is preferable to filtration, providing the precipitate be ſeveral times waſhed in a conſiderable proportion of water. The weight of the precipitate may indeed be aſcertained, by carefully weighing the filtre before and after the operation; but, when the quantity of precipitate is ſmall, the different proportions of moiſture retained by the paper, in a greater or leſſer degree of exſiccation, may prove a material ſource of error, which ought carefully to be guarded againſt.

CHAP. V.

Of Chemical Means for ſeparating the Particles of Bodies from each other, without Decompoſition, and for uniting them again.

I have already ſhown that there are two methods of dividing the particles of bodies, the *mechanical* and *chemical*. The former only ſeparates a ſolid maſs into a great number of ſmaller maſſes; and for theſe purpoſes various ſpecies of forces are employed, according to circumſtances, ſuch as the ſtrength of man or of animals, the weight of water applied through the means of hydraulic engines, the expanſive power of ſteam, the force of the wind, &c. By all theſe mechanical powers, we can never reduce ſubſtances into powder beyond a certain degree of fineneſs; and the ſmalleſt particle produced in this way, though it ſeems very minute to our organs, is ſtill in fact a mountain, when compared with the ultimate elementary particles of the pulverized ſubſtance.

The chemical agents, on the contrary, divide bodies into their primitive particles. If, for inſtance, a neutral ſalt be acted upon by theſe, it is divided, as far as is poſſible, without ceaſing to be a neutral ſalt. In this Chapter, I mean to give

give examples of this kind of diviſion of bodies, to which I ſhall add ſome account of the relative operations.

SECT. I.

Of the Solution of Salts.

In chemical language, the terms of *ſolution* and *diſſolution* have long been confounded, and have very improperly been indiſcriminately employed for expreſſing both the diviſion of the particles of a ſalt in a fluid, ſuch as water, and the diviſion of a metal in an acid. A few reflections upon the effects of theſe two operations will ſuffice to ſhow that they ought not to be confounded together. In the ſolution of ſalts, the ſaline particles are only ſeparated from each other, whilſt neither the ſalt nor the water are at all decompoſed; we are able to recover both the one and the other in the ſame quantity as before the operation. The ſame thing takes place in the ſolution of reſins in alkohol. During metallic diſſolutions, on the contrary, a decompoſition, either of the acid, or of the water which dilutes it, always takes place; the metal combines with oxygen, and is changed into an oxyd, and a gaſſeous ſubſtance is diſengaged; ſo that in reality none of the ſubſtan-

ces

ces employed remain, after the operation, in the ſame ſtate they were in before. This article is entirely confined to the conſideration of ſolution.

To underſtand properly what takes place during the ſolution of ſalts, it is neceſſary to know, that, in moſt of theſe operations, two diſtinct effects are complicated together, viz. ſolution by water, and ſolution by caloric; and, as the explanation of moſt of the phenomena of ſolution depends upon the diſtinction of theſe two circumſtances, I ſhall enlarge a little upon their nature.

Nitrat of potaſh, uſually called nitre or ſaltpetre, contains very little water of criſtallization, perhaps even none at all; yet this ſalt liquifies in a degree of heat very little ſuperior to that of boiling water. This liquifaction cannot therefore be produced by means of the water of criſtallization, but in conſequence of the ſalt being very fuſible in its nature, and from its paſſing from the ſolid to the liquid ſtate of aggregation, when but a little raiſed above the temperature of boiling water. All ſalts are in this manner ſuſceptible of being liquified by caloric, but in higher or lower degrees of temperature. Some of theſe, as the acetites of potaſh and ſoda, liquify with a very moderate heat, whilſt others, as ſulphat of potaſh, lime, &c. require the ſtrongeſt fires we are capable of producing. This liquifaction of ſalts by caloric produces exactly the ſame phenomena with the melting of ice; it is accompliſhed in each ſalt by a determinate degree of heat, which remains invariably the ſame during the whole time of the liquifaction. Caloric is employed, and becomes fixed during the melting of the ſalt, and is, on the contrary, diſengaged when the ſalt coagulates. Theſe are general phenomena which univerſally occur during the paſſage of every ſpecies of ſubſtance from the ſolid to the fluid ſtate of aggregation, and from fluid to ſolid.

Theſe phenomena ariſing from ſolution by caloric are always leſs or more conjoined with thoſe which take place during ſolutions in water. We cannot pour water upon a ſalt, on purpoſe to diſſolve it, without employing a compound ſolvent, both water and caloric; hence we may diſtinguiſh ſeveral different caſes of ſolution, according to the nature and mode of exiſtence of each ſalt. If, for inſtance, a ſalt be difficultly ſoluble in water, and readily ſo by caloric, it evidently follows, that this ſalt will be difficultly ſoluble in cold water, and conſiderably in hot water; ſuch is nitrat of potaſh, and more eſpecially oxygenated muriat of potaſh. If another ſalt be little ſoluble both in water and caloric, the difference of its ſolubility in cold and warm water will be very inconſiderable; ſulphat of lime is of this kind. From theſe conſiderations,

ſiderations, it follows, that there is a neceſſary relation between the following circumſtances; the ſolubility of a ſalt in cold water, its ſolubility in boiling water, and the degree of temperature at which the ſame ſalt liquifies by caloric, unaſſiſted by water; and that the difference of ſolubility in hot and cold water is ſo much greater in proportion to its ready ſolution in caloric, or in proportion to its ſuſceptibility of liquifying in a low degree of temperature.

The above is a general view of ſolution; but, for want of particular facts, and ſufficiently exact experiments, it is ſtill nothing more than an approximation towards a particular theory. The means of compleating this part of chemical ſcience is extremely ſimple; we have only to aſcertain how much of each ſalt is diſſolved by a certain quantity of water at different degrees of temperature; and as, by the experiments publiſhed by Mr de la Place and me, the quantity of caloric contained in a pound of water at each degree of the thermometer is accurately known, it will be very eaſy to determine, by ſimple experiments, the proportion of water and caloric required for ſolution by each ſalt, what quantity of caloric is abſorbed by each at the moment of liquifaction, and how much is diſengaged at the moment of criſtallization. Hence the reaſon why ſalts are more rapidly ſoluble in hot than in cold water is perfectly evident. In all ſolutions

tions of ſalts caloric is employed; when that is furniſhed intermediately from the ſurrounding bodies, it can only arrive ſlowly to the ſalt; whereas this is greatly accelerated when the requiſite caloric exiſts ready combined with the water of ſolution.

In general, the ſpecific gravity of water is augmented by holding ſalts in ſolution; but there are ſome exceptions to the rule. Some time hence, the quantities of radical, of oxygen, and of baſe, which conſtitute each neutral ſalt, the quantity of water and caloric neceſſary for ſolution, the increaſed ſpecific gravity communicated to water, and the figure of the elementary particles of the criſtals, will all be accurately known. From theſe all the circumſtances and phenomena of criſtallization will be explained, and by theſe means this part of chemiſtry will be compleated. Mr Seguin has formed the plan of a thorough inveſtigation of this kind, which he is extremely capable of executing.

The ſolution of ſalts in water requires no particular apparatus; ſmall glaſs phials of different ſizes, Pl. II. Fig. 16. and 17. pans of earthern ware, A, Fig. 1. and 2. long-necked matraſſes, Fig. 14. and pans or baſons of copper or of ſilver, Fig. 13. and 15. anſwer very well for theſe operations.

SECT. II.

Of Lixiviation.

This is an operation uſed in chemiſtry and manufactures for ſeparating ſubſtances which are ſoluble in water from ſuch as are inſoluble. The large vat or tub, Pl. II. Fig. 12. having a hole D near its bottom, containing a wooden ſpiget and foſſet or metallic ſtop-cock DE, is generally uſed for this purpoſe. A thin ſtratum of ſtraw is placed at the bottom of the tub; over this, the ſubſtance to be lixiviated is laid and covered by a cloth, then hot or cold water, according to the degree of ſolubility of the ſaline matter, is poured on. When the water is ſuppoſed to have diſſolved all the ſaline parts, it is let off by the ſtop-cock; and, as ſome of the water charged with ſalt neceſſarily adheres to the ſtraw and inſoluble matters, ſeveral freſh quantities of water are poured on. The ſtraw ſerves to ſecure a proper paſſage for the water, and may be compared to the ſtraws or glaſs rods uſed in filtrating, to keep the paper from touching the ſides of the funnel. The cloth which is laid over the matters under lixiviation prevents the water from making a hollow in theſe ſubſtances where it is poured on, through which it might eſcape without acting upon the whole maſs.

This operation is leſs or more imitated in chemical experiments; but as in theſe, eſpecially with analytical views, greater exactneſs is required, particular precautions muſt be employed, ſo as not to leave any ſaline or ſoluble part in the reſiduum. More water muſt be employed than in ordinary lixiviations, and the ſubſtances ought to be previouſly ſtirred up in the water before the clear liquor is drawn off, otherwiſe the whole maſs might not be equally lixiviated, and ſome parts might even eſcape altogether from the action of the water. We muſt likewiſe employ freſh portions of water in conſiderable quantity, until it comes off entirely free from ſalt, which we may aſcertain by means of the hydrometer formerly deſcribed.

In experiments with ſmall quantities, this operation is conveniently performed in jugs or matraſſes of glaſs, and by filtrating the liquor through paper in a glaſs funnel. When the ſubſtance is in larger quantity, it may be lixiviated in a kettle of boiling water, and filtrated through paper ſupported by cloth in the wooden frame, Pl. II. Fig. 3. and 4.; and in operations in the large way, the tub already mentioned muſt be uſed.

SECT. III.

Of Evaporation.

This operation is uſed for ſeparating two ſubſtances from each other, of which one at leaſt muſt be fluid, and whoſe degrees of volatility are conſiderably different. By this means we obtain a ſalt, which has been diſſolved in water, in its concrete form; the water, by heating, becomes combined with caloric, which renders it volatile, while the particles of the ſalt being brought nearer to each other, and within the ſphere of their mutual attraction, unite into the ſolid ſtate.

As it was long thought that the air had great influence upon the quantity of fluid evaporated, it will be proper to point out the errors which this opinion has produced. There certainly is a conſtant ſlow evaporation from fluids expoſed to the free air; and, though this ſpecies of evaporation may be conſidered in ſome degree as a ſolution in air, yet caloric has conſiderable influence in producing it, as is evident from the refrigeration which always accompanies this proceſs; hence we may conſider this gradual evaporation as a compound ſolution made partly in air, and partly in caloric. But the evaporation which takes place from a fluid kept continually boiling, is quite different in its nature, and in it the evaporation produced by the action of the air is exceedingly inconſiderable in compariſon with that which is occaſioned by caloric. This latter ſpecies may be termed *vaporization* rather than *evaporation.* This proceſs is not accelerated in proportion to the extent of evaporating ſurface, but in proportion to the quantities of caloric which combine with the fluid. Too free a current of cold air is often hurtful to this proceſs, as it tends to carry off caloric from the water, and conſequently retards its converſion into vapour. Hence there is no inconvenience produced by covering, in a certain degree, the veſſels in which liquids are evaporated by continual boiling, provided the covering body be of ſuch a nature as does not ſtrongly draw off the caloric, or, to uſe an expreſſion of Dr Franklin's, provided it be a bad conductor of heat. In this caſe, the vapours eſcape through ſuch opening as is left, and at leaſt as much is evaporated, frequently more than when free acceſs is allowed to the external air.

As during evaporation the fluid carried off by caloric is entirely loſt, being ſacrificed for the ſake of the fixed ſubſtances with which it was combined, this proceſs is only employed where the fluid is of ſmall value, as water, for inſtance. But,

But, when the fluid is of more conſequence, we have recourſe to diſtillation, in which proceſs we preſerve both the fixed ſubſtance and the volatile fluid. The veſſels employed for evaporation are baſons or pans of copper, ſilver, or lead, Pl. II. Fig. 13. and 15. or capſules of glaſs, porcellain, or ſtone ware, Pl. II. A, Fig. 1. and 2. Pl. III. Fig. 3 and 4. The beſt utenſils for this purpoſe are made of the bottoms of glaſs retorts and matraſſes, as their equal thinneſs renders them more fit than any other kind of glaſs veſſel for bearing a briſk fire and ſudden alterations of heat and cold without breaking.

As the method of cutting theſe glaſs veſſels is no where deſcribed in books, I ſhall here give a deſcription of it, that they may be made by chemiſts for themſelves out of ſpoiled retorts, matraſſes, and recipients, at a much cheaper rate than any which can be procured from glaſs manufacturers. The inſtrument, Pl. III. Fig. 5. conſiſting of an iron ring AC, fixed to the rod AB, having a wooden handle D, is employed as follows: Make the ring red hot in the fire, and put it upon the matraſs G, Fig. 6. which is to be cut; when the glaſs is ſufficiently heated, throw on a little cold water, and it will generally break exactly at the circular line heated by the ring.

Small flaſks or phials of thin glaſs are exceeding good veſſels for evaporating ſmall quantities of fluid; they are very cheap, and ſtand the fire remarkably. One or more of theſe may be placed upon a ſecond grate above the furnace, Pl. III. Fig. 2. where they will only experience a gentle heat. By this means a great number of experiments may be carried on at one time. A glaſs retort, placed in a ſand-bath, and covered with a dome of baked earth, Pl. III. Fig. 1. anſwers pretty well for evaporations; but in this way it is always conſiderably ſlower, and is even liable to accidents; as the ſand heats unequally, and the glaſs cannot dilate in the ſame unequal manner, the retort is very liable to break. Sometimes the ſand ſerves exactly the office of the iron ring formerly mentioned; for, if a ſingle drop of vapour, condenſed into liquid, happens to fall upon the heated part of the veſſel, it breaks circularly at that place. When a very intenſe fire is neceſſary, earthen crucibles may be uſed; but we generally uſe the word *evaporation* to expreſs what is produced by the temperature of boiling water, or not much higher.

SECT. IV.

Of Criſtallization.

In this proceſs the integrant parts of a ſolid body, ſeparated from each other by the intervention of a fluid, are made to exert the mutual attraction of aggregation, ſo as to coaleſce and reproduce a ſolid maſs. When the particles of a body are only ſeparated by caloric, and the ſubſtance is thereby retained in the liquid ſtate, all that is neceſſary for making it criſtallize, is to remove a part of the caloric which is lodged between its particles, or, in other words, to cool it. If this refrigeration be ſlow, and the body be at the ſame time left at reſt, its particles aſſume a regular arrangement, and criſtallization, properly ſo called, takes place; but, if the refrigeration is made rapidly, or if the liquor be agitated at the moment of its paſſage to the concrete ſtate, the criſtallization is irregular and confuſed.

The ſame phenomena occur with watery ſolutions, or rather in thoſe made partly in water, and partly by caloric. So long as there remains a ſufficiency of water and caloric to keep the particles of the body aſunder beyond the ſphere of of their mutual attraction, the ſalt remains in the fluid ſtate; but, whenever either caloric or water is not preſent in ſufficient quantity, and the attraction of the particles for each other becomes ſuperior to the power which keeps them aſunder, the ſalt recovers its concrete form, and the criſtals produced are the more regular in proportion as the evaporation has been ſlower and more tranquilly performed.

All the phenomena we formerly mentioned as taking place during the ſolution of ſalts, occur in a contrary ſenſe during their criſtallization. Caloric is diſengaged at the inſtant of their aſſuming the ſolid ſtate, which furniſhes an additional proof of ſalt being held in ſolution by the compound action of water and caloric. Hence, to cauſe ſalts to criſtallize which readily liquify by means of caloric, it is not ſufficient to carry off the water which held them in ſolution, but the caloric united to them muſt likewiſe be removed. Nitrat of potaſh, oxygenated muriat of potaſh, alum, ſulphat of ſoda, &c. are examples of this circumſtance, as, to make theſe ſalts criſtallize, refrigeration muſt be added to evaporation. Such ſalts, on the contrary, as require little caloric for being kept in ſolution, and which, from that circumſtance, are nearly equally ſoluble in cold and warm water, are criſtallizable by ſimply carrying off the water which holds them in ſolution, and even

even recover their ſolid ſtate in boiling water; ſuch are ſulphat of lime, muriat of potaſh and of ſoda, and ſeveral others.

The art of refining ſaltpetre depends upon theſe properties of ſalts, and upon their different degrees of ſolubility in hot and cold water. This ſalt, as produced in the manufactories by the firſt operation, is compoſed of many different ſalts; ſome are deliqueſcent, and not ſuſceptible of being criſtallized, ſuch as the nitrat and muriat of lime; others are almoſt equally ſoluble in hot and cold water, as the muriats of potaſh and of ſoda; and, laſtly, the ſaltpetre, or nitrat of potaſh, is greatly more ſoluble in hot than it is in cold water. The operation is begun, by pouring upon this mixture of ſalts as much water as will hold even the leaſt ſoluble, the muriats of ſoda and of potaſh, in ſolution; ſo long as it is hot, this quantity readily diſſolves all the ſaltpetre, but, upon cooling, the greater part of this ſalt criſtallizes, leaving about a ſixth part remaining diſſolved, and mixed with the nitrat of lime and the two muriats. The nitre obtained by this proceſs is ſtill ſomewhat impregnated with other ſalts, becauſe it has been criſtallized from water in which theſe abound: It is completely purified from theſe by a ſecond ſolution in a ſmall quantity of boiling water, and ſecond criſtallization. The water remaining after theſe criſtallizations of nitre is ſtill loaded with a mixture

ture of ſaltpetre, and other ſalts; by farther evaporation, crude ſaltpetre, or rough-petre, as the workmen call it, is procured from it, and this is purified by two freſh ſolutions and criſtallizations.

The deliqueſcent earthy ſalts which do not contain the nitric acid are rejected in this manufacture; but thoſe which conſiſt of that acid neutralized by an earthy baſe are diſſolved in water, the earth is precipitated by means of potaſh, and allowed to ſubſide; the clear liquor is then decanted, evaporated, and allowed to criſtallize. The above management for refining ſaltpetre may ſerve as a general rule for ſeparating ſalts from each other which happen to be mixed together. The nature of each muſt be conſidered, the proportion in which each diſſolves in given quantities of water, and the different ſolubility of each in hot and cold water. If to theſe we add the property which ſome ſalts poſſeſs, of being ſoluble in alkohol, or in a mixture of alkohol and water, we have many reſources for ſeparating ſalts from each other by means of criſtallization, though it muſt be allowed that it is extremely difficult to render this ſeparation perfectly complete.

The veſſels uſed for criſtallization are pans of earthen ware, A, Pl. II. Fig. 1. and 2. and large flat diſhes, Pl. III. Fig. 7. When a ſaline ſolution is to be expoſed to a ſlow evaporation in the heat of the atmoſphere, with free acceſs of air, veſſels of ſome depth, Pl. III. Fig. 3. muſt be employed, that there may be a conſiderable body of liquid; by this means the criſtals produced are of conſiderable ſize, and remarkably regular in their figure.

Every ſpecies of ſalt criſtallizes in a peculiar form, and even each ſalt varies in the form of its criſtals according to circumſtances, which take place during criſtallization. We muſt not from thence conclude that the ſaline particles of each ſpecies are indeterminate in their figures: The primative particles of all bodies, eſpecially of ſalts, are perfectly conſtant in their ſpecific forms; but the criſtals which form in our experiments are compoſed of congeries of minute particles, which, though perfectly equal in ſize and ſhape, may aſſume very diſſimilar arrangements, and conſequently produce a vaſt variety of regular forms, which have not the ſmalleſt apparent reſemblance to each other, nor to the original criſtal. This ſubject has been very ably treated by the Abbe Haüy, in ſeveral memoirs preſented to the Academy, and in his work upon the ſtructure of criſtals: It is only neceſſary to extend generally to the claſs of ſalts the principles he has particularly applied to ſome criſtalized ſtones.

SECT. V.

Of Simple Diſtillation.

As diſtillation has two diſtinct objects to accompliſh, it is diviſible into ſimple and compound; and, in this ſection, I mean to confine myſelf entirely to the former. When two bodies, of which one is more volatile than the other, or has more affinity to caloric, are ſubmitted to diſtillation, our intention is to ſeparate them from each other: The more volatile ſubſtance aſſumes the form of gas, and is afterwards condenſed by refrigeration in proper veſſels. In this caſe diſtillation, like evaporation, becomes a ſpecies of mechanical operation, which ſeparates two ſubſtances from each other without decompoſing or altering the nature of either. In evaporation, our only object is to preſerve the fixed body, without paying any regard to the volatile matter; whereas, in diſtillation, our principal attention is generally paid to the volatile ſubſtance, unleſs when we intend to preſerve both the one and the other. Hence, ſimple diſtillation is nothing more than evaporation produced in cloſe veſſels.

The moſt ſimple diſtilling veſſel is a ſpecies of bottle or matraſs, A, Pl. III. Fig. 8. which has been

been bent from its original form BC to BD, and which is then called a retort; when uſed, it is placed either in a reverberatory furnace, Pl. XIII. Fig. 2. or in a ſand bath under a dome of baked earth, Pl. III. Fig. 1. To receive and condenſe the products, we adapt a recipient, E, Pl. III. Fig. 9. which is luted to the retort. Sometimes, more eſpecially in pharmaceutical operations, the glaſs or ſtone ware cucurbit, A, with its capital B, Pl. III. Fig. 12. or the glaſs alembic and capital, Fig. 13. of one piece, is employed. This latter is managed by means of a tubulated opening T, fitted with a ground ſtopper of criſtal; the capital, both of the cucurbit and alembic, has a furrow or trench, *r r*, intended for conveying the condenſed liquor into the beak RS, by which it runs out. As, in almoſt all diſtillations, expanſive vapours are produced, which might burſt the veſſels employed, we are under the neceſſity of having a ſmall hole, T, Fig. 9. in the balloon or recipient, through which theſe may find vent; hence, in this way of diſtilling, all the products which are permanently aëriform are entirely loſt, and even ſuch as difficultly loſe that ſtate have not ſufficient ſpace to condenſe in the balloon: This apparatus is not, therefore, proper for experiments of inveſtigation, and can only be admitted in the ordinary operations of the laboratory or in pharmacy. In the article appropriated for compound diſtillation, I ſhall explain the various methods which have been contrived for preſerving the whole products from bodies in this proceſs.

As glaſs or earthen veſſels are very brittle, and do not readily bear ſudden alterations of heat and cold, every well regulated laboratory ought to have one or more alembics of metal for diſtilling water, ſpiritous liquors, eſſential oils, &c. This apparatus conſiſts of a cucurbit and capital of tinned copper or braſs, Pl. III. Fig. 15. and 16. which, when judged proper, may be placed in the water bath, D, Fig. 17. In diſtillations, eſpecially of ſpiritous liquors, the capital muſt be furniſhed with a refrigetory, SS, Fig. 16. kept continually filled with cold water; when the water becomes heated, it is let off by the ſtop-cock, R, and renewed with a freſh ſupply of cold water. As the fluid diſtilled is converted into gas by means of caloric furniſhed by the fire of the furnace, it is evident that it could not condenſe, and, conſequently, that no diſtillation, properly ſpeaking, could take place, unleſs it is made to depoſit in the capital all the caloric it received in the cucurbit; with this view, the ſides of the capital muſt always be preſerved at a lower temperature than is neceſſary for keeping the diſtilling ſubſtance in the ſtate of gas, and the water in the refrigetory is intended for this purpoſe.

Water

Water is converted into gas by the temperature of 80° (212°), alkohol by 67° (182.75°), ether by 32° (104°); hence theſe ſubſtances cannot be diſtilled, or, rather, they will fly off in the ſtate of gas, unleſs the temperature of the refrigetory be kept under theſe reſpective degrees.

In the diſtillation of ſpiritous, and other expanſive liquors, the above deſcribed refrigetory is not ſufficient for condenſing all the vapours which ariſe; in this caſe, therefore, inſtead of receiving the diſtilled liquor immediately from the beak, TU, of the capital into a recipient, a worm is interpoſed between them. This inſtrument is repreſented Pl. III. Fig. 18. contained in a worm tub of tinned copper, it conſiſts of a metallic tube bent into a conſiderable number of ſpiral revolutions. The veſſel which contains the worm is kept full of cold water, which is renewed as it grows warm. This contrivance is employed in all diſtilleries of ſpirits, without the intervention of a capital and refrigetory, properly ſo called. The one repreſented in the plate is furniſhed with two worms, one of them being particularly appropriated to diſtillations of odoriferous ſubſtances.

In ſome ſimple diſtillations it is neceſſary to interpoſe an adopter between the retort and receiver, as ſhown Pl. III. Fig. 11. This may ſerve two different purpoſes, either to ſeparate two products of different degrees of volatility, or to remove the receiver to a greater diſtance from the furnace, that it may be leſs heated. But theſe, and ſeveral other more complicated inſtruments of ancient contrivance, are far from producing the accuracy requiſite in modern chemiſtry, as will be readily perceived when I come to treat of compound diſtillation.

SECT. VI.

Of Sublimation.

This term is applied to the diſtillation of ſubſtances which condenſe in a concrete or ſolid form, ſuch as the ſublimation of ſulphur, and of muriat of ammoniac, or ſal ammoniac. Theſe operations may be conveniently performed in the ordinary diſtilling veſſels already deſcribed, though, in the ſublimation of ſulphur, a ſpecies of veſſels, named Alludels, have been uſually employed. Theſe are veſſels of ſtone or porcelain ware, which adjuſt to each other over a cucurbit containing the ſulphur to be ſublimed. One of the beſt ſubliming veſſels, for ſubſtances which are not very volatile, is a flaſk,

or

or phial of glaſs, ſunk about two thirds into a ſand bath; but in this way we are apt to loſe a part of the products. When theſe are wiſhed to be entirely preſerved, we muſt have recourſe to the pneumato-chemical diſtilling apparatus, to be deſcribed in the following chapter.

CHAP. VI.

Of Pneumato-chemical Diſtillations, Metallic Diſſolutions, and ſome other operations which require very complicated inſtruments.

SECT. I.

Of Compound and Pneumato-chemical Diſtillations.

IN the preceding chapter, I have only treated of diſtillation as a ſimple operation, by which two ſubſtances, differing in degrees of volatility, may be ſeparated from each other; but diſtillation often actually decompoſes the ſubſtances ſubmitted to its action, and becomes one of the moſt complicated operations in chemiſtry. In every diſtillation, the ſubſtance diſtilled muſt be brought to the ſtate of gas, in the cucurbit or retort, by combination with caloric: In ſimple diſtillation, this caloric is given out in the refrigeratory or in the worm, and the ſubſtance again recovers its liquid or ſolid form, but the ſubſtances ſubmitted to compound diſtillation are

are abſolutely decompounded; one part, as for inſtance the charcoal they contain, remains fixed in the retort, and all the reſt of the elements are reduced to gaſſes of different kinds. Some of theſe are ſuſceptible of being condenſed, and of recovering their ſolid or liquid forms, whilſt others are permanently aëriform; one part of theſe are abſorbable by water, ſome by the alkalies, and others are not ſuſceptible of being abſorbed at all. An ordinary diſtilling apparatus, ſuch as has been deſcribed in the preceding chapter, is quite inſufficient for retaining or for ſeparating theſe diverſified products, and we are obliged to have recourſe, for this purpoſe, to methods of a more complicated nature.

The apparatus I am about to deſcribe is calculated for the moſt complicated diſtillations, and may be ſimplified according to circumſtances. It conſiſts of a tubulated glaſs retort A, Pl. IV. Fig. 1. having its beak fitted to a tubulated balloon or recipient BC; to the upper orifice D of the balloon a bent tube DE*fg* is adjuſted, which, at its other extremity *g*, is plunged into the liquor contained in the bottle L, with three necks *xxx*. Three other ſimilar bottles are connected with this firſt one, by means of three ſimilar bent tubes diſpoſed in the ſame manner; and the fartheſt neck of the laſt bottle is connected with a jar in a pneumato-chemical apparatus, by means of a bent

tube.

tube *. A determinate weight of diſtilled water is uſually put into the firſt bottle, and the other three have each a ſolution of cauſtic potaſh in water. The weight of all theſe bottles, and of the water and alkaline ſolution they contain, muſt be accurately aſcertained. Every thing being thus diſpoſed, the junctures between the retort and recipient, and of the tube D of the latter, muſt be luted with fat lute, covered over with ſlips of linen, ſpread with lime and white of egg; all the other junctures are to be ſecured by a lute made of wax and roſin melted together.

When all theſe diſpoſitions are completed, and when, by means of heat applied to the retort A, the ſubſtance it contains becomes decompoſed, it is evident that the leaſt volatile products muſt condenſe or ſublime in the beak or neck of the retort itſelf, where moſt of the concrete ſubſtances will fix themſelves. The more volatile ſubſtances, as the lighter oils, ammoniac, and ſeveral others, will condenſe in the recipient GC, whilſt the gaſſes, which are not ſuſceptible of condenſation by cold, will paſs on by the tubes, and boil up through the liquors in the ſeveral bottles. Such as are abſorbable by

---

* The repreſentation of this apparatus, Pl. IV. Fig. 1. will convey a much better idea of its diſpoſition than can poſſibly be given by the moſt laboured deſcription.—E.

by water will remain in the firſt bottle, and thoſe which cauſtic alkali can abſorb will remain in the others; whilſt ſuch gaſſes as are not ſuſceptible of abſorption, either by water or alkalies, will eſcape by the tube RM, at the end of which they may be received into jars in a pneumato-chemical apparatus. The charcoal and fixed earth, &c. which form the ſubſtance or reſiduum, anciently called *caput mortuum*, remain behind in the retort.

In this manner of operating, we have always a very material proof of the accuracy of the analyſis, as the whole weights of the products taken together, after the proceſs is finiſhed, muſt be exactly equal to the weight of the original ſubſtance ſubmitted to diſtillation. Hence, for inſtance, if we have operated upon eight ounces of ſtarch or gum arabic, the weight of the charry reſiduum in the retort, together with that of all the products gathered in its neck and the balloon, and of all the gas received into the jars by the tube RM added to the additional weight acquired by the bottles, muſt, when taken together, be exactly eight ounces. If the product be leſs or more, it proceeds from error, and the experiment muſt be repeated until a ſatisfactory reſult be procured, which ought not to differ more than ſix or eight grains in the pound from the weight of the ſubſtance ſubmitted to experiment.

In experiments of this kind, I for a long time met with an almoſt inſurmountable difficulty, which muſt at laſt have obliged me to deſiſt altogether, but for a very ſimple method of avoiding it, pointed out to me by Mr Haſſenfratz. The ſmalleſt diminution in the heat of the furnace, and many other circumſtances inſeparable from this kind of experiments, cauſe frequent reabſorptions of gas; the water in the ciſtern of the pneumato-chemical apparatus ruſhes into the laſt bottle through the tube RM, the ſame circumſtance happens from one bottle into another, and the fluid is often forced even into the recipient C. This accident is prevented by uſing bottles having three necks, as repreſented in the plate, into one of which, in each bottle, a capillary glaſs-tube *St*, *st*, *st*, *st*, is adapted, ſo as to have its lower extremity *t* immerſed in the liquor. If any abſorption takes place, either in the retort, or in any of the bottles, a ſufficient quantity of external air enters, by means of theſe tubes, to fill up the void; and we get rid of the inconvenience at the price of having a ſmall mixture of common air with the products of the experiment, which is thereby prevented from failing altogether. Though theſe tubes admit the external air, they cannot permit any of the gaſſeous ſubſtances to eſcape, as they are always ſhut below by the water of the bottles.

It

It is evident that, in the courſe of experiments with this apparatus, the liquor of the bottles muſt riſe in theſe tubes in proportion to the preſſure ſuſtained by the gas or air contained in the bottles; and this preſſure is determined by the height and gravity of the column of fluid contained in all the ſubſequent bottles. If we ſuppoſe that each bottle contains three inches of fluid, and that there are three inches of water in the ciſtern of the connected apparatus above the orifice of the tube RM, and allowing the gravity of the fluids to be only equal to that of water, it follows that the air in the firſt bottle muſt ſuſtain a preſſure equal to twelve inches of water; the water muſt therefore riſe twelve inches in the tube S, connected with the firſt bottle, nine inches in that belonging to the ſecond, ſix inches in the third, and three in the laſt; wherefore theſe tubes muſt be made ſomewhat more than twelve, nine, ſix, and three inches long reſpectively, allowance being made for oſcillatory motions, which often take place in the liquids. It is ſometimes neceſſary to introduce a ſimilar tube between the retort and recipient; and, as the tube is not immerſed in fluid at its lower extremity, until ſome has collected in the progreſs of the diſtillation, its upper end muſt be ſhut at firſt with a little lute, ſo as to be opened according to neceſſity, or after there

there is ſufficient liquid in the recipient to ſecure its lower extremity.

This apparatus cannot be uſed in very accurate experiments, when the ſubſtances intended to be operated upon have a very rapid action upon each other, or when one of them can only be introduced in ſmall ſucceſſive portions, as in ſuch as produce violent efferveſcence when mixed together. In ſuch caſes, we employ a tubulated retort A, Pl. VII. Fig. 1. into which one of the ſubſtances is introduced, preferring always the ſolid body, if any ſuch is to be treated, we then lute to the opening of the retort a bent tube BCDA, terminating at its upper extremity B in a funnel, and at its other end A in a capillary opening. The fluid material of the experiment is poured into the retort by means of this funnel, which muſt be made of ſuch a length, from B to C, that the column of liquid introduced may counterbalance the reſiſtance produced by the liquors contained in all the bottles, Pl. IV. Fig. 1.

Thoſe who have not been accuſtomed to uſe the above deſcribed diſtilling apparatus may perhaps be ſtartled at the great number of openings which require luting, and the time neceſſary for making all the previous preparations in experiments of this kind. It is very true that, if we take into account all the neceſſary weighings of materials and products, both before and after the experiments, theſe preparatory and ſucceeding ſteps require much more time and attention than the experiment itſelf. But, when the experiment ſucceeds properly, we are well rewarded for all the time and trouble beſtowed, as by one proceſs carried on in this accurate manner much more juſt and extenſive knowledge is acquired of the nature of the vegetable or animal ſubſtance thus ſubmitted to inveſtigation, than by many weeks aſſiduous labour in the ordinary method of proceeding.

When in want of bottles with three orifices, thoſe with two may be uſed; it is even poſſible to introduce all the three tubes at one opening, ſo as to employ ordinary wide-mouthed bottles, provided the opening be ſufficiently large. In this caſe we muſt carefully fit the bottles with corks very accurately cut, and boiled in a mixture of oil, wax, and turpentine. Theſe corks are pierced with the neceſſary holes for receiving the tubes by means of a round file, as in Pl. IV. Fig. 8.

SECT. II.

Of Metallic Diſſolutions.

I have already pointed out the difference between ſolution of ſalts in water and metallic diſſolutions. The former requires no particular veſſels, whereas the latter requires very complicated veſſels of late invention, that we may not loſe any of the products of the experiment, and may thereby procure truly concluſive reſults of the phenomena which occur. The metals, in general, diſſolve in acids with efferveſcence, which is only a motion excited in the ſolvent by the diſengagement of a great number of bubbles of air or aëriform fluid, which proceed from the ſurface of the metal, and break at the ſurface of the liquid.

Mr Cavendiſh and Dr Prieſtley were the firſt inventors of a proper apparatus for collecting theſe elaſtic fluids. That of Dr Prieſtley is extremely ſimple, and conſiſts of a bottle A, Pl. VII. Fig. 2. with its cork B, through which paſſes the bent glaſs tube BC, which is engaged under a jar filled with water in the pneumato-chemical apparatus, or ſimply in a baſon full of water. The metal is firſt introduced into the bottle,

bottle, the acid is then poured over it, and the bottle is inſtantly cloſed with its cork and tube, as repreſented in the plate. But this apparatus has its inconveniencies. When the acid is much concentrated, or the metal much divided, the effervefcence begins before we have time to cork the bottle properly, and ſome gas eſcapes, by which we are prevented from aſcertaining the quantity diſengaged with rigorous exactneſs. In the next place, when we are obliged to employ heat, or when heat is produced by the proceſs, a part of the acid diſtills, and mixes with the water of the pneumato-chemical apparatus, by which means we are deceived in our calculation of the quantity of acid decompoſed. Beſides theſe, the water in the ciſtern of the apparatus abſorbs all the gas produced which is ſuſceptible of abſorption, and renders it impoſſible to collect theſe without loſs.

To remedy theſe inconveniencies, I at firſt uſed a bottle with two necks, Pl. VII. Fig. 3. into one of which the glaſs funnel BC is luted ſo as to prevent any air eſcaping; a glaſs rod DE is fitted with emery to the funnel, ſo as to ſerve the purpoſe of a ſtopper. When it is uſed, the matter to be diſſolved is firſt introduced into the bottle, and the acid is then permitted to paſs in as ſlowly as we pleaſe, by raiſing the glaſs rod gently as often as is neceſſary until ſaturation is produced.

Another

Another method has been ſince employed, which ſerves the ſame purpoſe, and is preferable to the laſt deſcribed in ſome inſtances. This conſiſts in adapting to one of the mouths of the bottle A, Pl. VII. Fig. 4. a bent tube DEFG, having a capillary opening at D, and ending in a funnel at G. This tube is ſecurely luted to the mouth C of the bottle. When any liquid is poured into the funnel, it falls down to F; and, if a ſufficient quantity be added, it paſſes by the curvature E, and falls ſlowly into the bottle, ſo long as freſh liquor is ſupplied at the funnel. The liquor can never be forced out of the tube, and no gas can eſcape through it, becauſe the weight of the liquid ſerves the purpoſe of an accurate cork.

To prevent any diſtillation of acid, eſpecially in diſſolutions accompanied with heat, this tube is adapted to the retort A, Pl. VII. Fig. 1. and a ſmall tubulated recipient, M, is applied, in which any liquor which may diſtill is condenſed. On purpoſe to ſeparate any gas that is abſorbable by water, we add the double necked bottle L, half filled with a ſolution of cauſtic potaſh; the alkali abſorbs any carbonic acid gas, and uſually only one or two other gaſſes paſs into the jar of the connected pneumato-chemical apparatus through the tube NO. In the firſt chapter of this third part we have directed how theſe are to be ſeparated and examined. If

If one bottle of alkaline ſolution be not thought ſufficient, two, three, or more, may be added.

SECT. III.

Apparatus neceſſary in Experiments upon Vinous and Putrefactive Fermentations.

For theſe operations a peculiar apparatus, eſpecially intended for this kind of experiment, is requiſite. The one I am about to deſcribe is finally adopted, as the beſt calculated for the purpoſe, after numerous corrections and improvements. It conſiſts of a large matraſs, A, Pl. X. fig. 1. holding about twelve pints, with a cap of braſs *a b*, ſtrongly cemented to its mouth, and into which is ſcrewed a bent tube *c d*, furniſhed with a ſtop-cock *e*. To this tube is joined the glaſs recipient B, having three openings, one of which communicates with the bottle C, placed below it. To the poſterior opening of this recipient is fitted a glaſs tube *g h i*, cemented at *g* and *i* to collets of braſs, and intended to contain a very deliqueſcent concrete neutral ſalt, ſuch as nitrat or muriat of lime, acetite of potaſh, &c. This tube communicates with two bottles D and E, filled to *x* and *y* with a ſolution of cauſtic potaſh.

All the parts of this machine are joined together by accurate ſcrews, and the touching parts have greaſed leather interpoſed, to prevent any paſſage of air. Each piece is likewiſe furniſhed with two ſtop-cocks, by which its two extremities may be cloſed, ſo that we can weigh each ſeparately at any period of the operation.

The fermentable matter, ſuch as ſugar, with a proper quantity of yeaſt, and diluted with water, is put into the matraſs. Sometimes, when the fermentation is too rapid, a conſiderable quantity of froth is produced, which not only fills the neck of the matraſs, but paſſes into the recipient, and from thence runs down into the bottle C. On purpoſe to collect this ſcum and muſt, and to prevent it from reaching the tube filled with deliqueſcent ſalts, the recipient and connected bottle are made of conſiderable capacity.

In the vinous fermentation, only carbonic acid gas is diſengaged, carrying with it a ſmall proportion of water in ſolution. A great part of this water is depoſited in paſſing through the tube *g h i*, which is filled with a deliqueſcent ſalt in groſs powder, and the quantity is aſcertained by the augmentation of the weight of the ſalt. The carbonic acid gas bubbles up through the alkaline ſolution in the bottle D, to which it is conveyed by the tube *k l m*. Any ſmall portion which may not be abſorbed by this firſt

firſt bottle is ſecured by the ſolution in the ſecond bottle E, ſo that nothing, in general, paſſes into the jar F. except the common air contained in the veſſels at the commencement of the experiment.

The ſame apparatus anſwers extremely well for experiments upon the putrefactive fermentation; but, in this caſe, a conſiderable quantity of hydrogen gas is diſengaged through the tube *q r s t u*, by which it is conveyed into the jar F; and, as this diſengagement is very rapid, eſpecially in ſummer, the jar muſt be frequently changed. Theſe putrefactive fermentations require conſtant attendance from the above circumſtance, whereas the vinous fermentation hardly needs any. By means of this apparatus we can aſcertain, with great preciſion, the weights of the ſubſtances ſubmitted to fermentation, and of the liquid and aëriform products which are diſengaged. What has been already ſaid in Part I. Chap. XIII. upon the products of the vinous fermentation, may be conſulted.

SECT. IV.

Apparatus for the Decompoſition of Water.

Having already given an account, in the firſt part of this work, of the experiments relative to the decompoſition of water, I ſhall avoid any unneceſſary repetitions, and only give a few ſummary obſervations upon the ſubject in this ſection. The principal ſubſtances which have the power of decompoſing water are iron and charcoal; for which purpoſe, they require to be made red hot, otherwiſe the water is only reduced into vapours, and condenſes afterwards by refrigeration, without ſuſtaining the ſmalleſt alteration. In a red heat, on the contrary, iron or charcoal carry off the oxygen from its union with hydrogen; in the firſt caſe, black oxyd of iron is produced, and the hydrogen is diſengaged pure in form of gas; in the other caſe, carbonic acid gas is formed, which diſengages, mixed with the hydrogen gas; and this latter is commonly carbonated, or holds charcoal in ſolution.

A muſket barrel, without its breach pin, anſwers exceedingly well for the decompoſition of water, by means of iron, and one ſhould be choſen

choſen of conſiderable length, and pretty ſtrong. When too ſhort, ſo as to run the riſk of heating the lute too much, a tube of copper is to be ſtrongly ſoldered to one end. The barrel is placed in a long furnace, CDEF, Pl. VII. Fig. 11. ſo as to have a few degrees of inclination from E to F; a glaſs retort A, is luted to the upper extremity E, which contains water, and is placed upon the furnace VVXX. The lower extremity F is luted to a worm SS, which is connected with the tubulated bottle H, in which any water diſtilled without decompoſition, during the operation, collects, and the diſengaged gas is carried by the tube KK to jars in a pneumato-chemical apparatus. Inſtead of the retort a funnel may be employed, having its lower part ſhut by a ſtop-cock, through which the water is allowed to drop gradually into the gun-barrel. Immediately upon getting into contact with the heated part of the iron, the water is converted into ſteam, and the experiment proceeds in the ſame manner as if it were furniſhed in vapours from the retort.

In the experiment made by Mr Meuſnier and me before a committee of the Academy, we uſed every precaution to obtain the greateſt poſſible preciſion in the reſult of our experiment, having even exhauſted all the veſſels employed before we began, ſo that the hydrogen gas obtained might be free from any mixture of azotic gas. The reſults of that experiment will hereafter be given at large in a particular memoir.

In numerous experiments, we are obliged to uſe tubes of glaſs, porcelain, or copper, inſtead of gun-barrels; but glaſs has the diſadvantage of being eaſily melted and flattened, if the heat be in the ſmalleſt degree raiſed too high; and porcelain is moſtly full of ſmall minute pores, through which the gas eſcapes, eſpecially when compreſſed by a column of water. For theſe reaſons I procured a tube of braſs, which Mr de la Briche got caſt and bored out of the ſolid for me at Straſburg, under his own inſpection. This tube is extremely convenient for decompoſing alkohol, which reſolves into charcoal, carbonic acid gas, and hydrogen gas; it may likewiſe be uſed with the ſame advantage for decompoſing water by means of charcoal, and in a great number of experiments of this nature.

CHAP. VII.

Of the Compoſition and Application of Lutes.

THE neceſſity of properly ſecuring the junctures of chemical veſſels to prevent the eſcape of any of the products of experiments, muſt be ſufficiently apparent; for this purpoſe lutes are employed, which ought to be of ſuch a nature as to be equally impenetrable to the moſt ſubtile ſubſtances, as glaſs itſelf, through which only caloric can eſcape.

This firſt object of lutes is very well accompliſhed by bees wax, melted with about an eighth part of turpentine. This lute is very eaſily managed, ſticks very cloſely to glaſs, and is very difficultly penetrable; it may be rendered more conſiſtent, and leſs or more hard or pliable, by adding different kinds of reſinous matters. Though this ſpecies of lute anſwers extremely well for retaining gaſſes and vapours, there are many chemical experiments which produce conſiderable heat, by which this lute becomes liquified, and conſequently the expanſive vapours muſt very readily force through and eſcape.

For

For ſuch caſes, the following fat lute is the beſt hitherto diſcovered, though not without its diſadvantages, which ſhall be pointed out. Take very pure and dry unbaked clay, reduced to a very fine powder, put this into a braſs mortar, and beat it for ſeveral hours with a heavy iron peſtle, dropping in ſlowly ſome boiled lintſeed oil; this is oil which has been oxygenated, and has acquired a drying quality, by being boiled with litharge. This lute is more tenacious, and applies better, if amber varniſh be uſed inſtead of the above oil. To make this varniſh, melt ſome yellow amber in an iron laddle, by which operation it loſes a part of its ſuccinic acid, and eſſential oil, and mix it with lintſeed oil. Though the lute prepared with this varniſh is better than that made with boiled oil, yet, as its additional expence is hardly compenſated by its ſuperior quality, it is ſeldom uſed.

The above fat lute is capable of ſuſtaining a very violent degree of heat, is impenetrable by acids and ſpiritous liquors, and adheres exceedingly well to metals, ſtone-ware, or glaſs, providing they have been previouſly rendered perfectly dry. But if, unfortunately, any of the liquor in the courſe of an experiment gets through, either between the glaſs and the lute, or between the layers of the lute itſelf, ſo as to moiſten the part, it is extremely difficult to cloſe the

the opening. This is the chief inconvenience which attends the uſe of fat lute, and perhaps the only one it is ſubject to. As it is apt to ſoften by heat, we muſt ſurround all the junctures with ſlips of wet bladder applied over the luting, and fixed on by pack-thread tied round both above and below the joint; the bladder, and conſequently the lute below, muſt be farther ſecured by a number of turns of pack-thread all over it. By theſe precautions, we are free from every danger of accident; and the junctures ſecured in this manner may be conſidered, in experiments, as hermetically ſealed.

It frequently happens that the figure of the junctures prevents the application of ligatures, which is the caſe with the three-necked bottles formerly deſcribed; and it even requires great addreſs to apply the twine without ſhaking the apparatus; ſo that, where a number of junctures require luting, we are apt to diſplace ſeveral while ſecuring one. In theſe caſes, we may ſubſtitute ſlips of linen, ſpread with white of egg and lime mixed together, inſtead of the wet bladder. Theſe are applied while ſtill moiſt, and very ſpeedily dry and acquire conſiderable hardneſs. Strong glue diſſolved in water may anſwer inſtead of white of egg. Theſe fillets are uſefully applied likewiſe over junctures luted together with wax and roſin.

Before applying a lute, all the junctures of the veſſels muſt be accurately and firmly fitted to each other, ſo as not to admit of being moved. If the beak of a retort is to be luted to the neck of a recipient, they ought to fit pretty accurately; otherwiſe we muſt fix them, by introducing ſhort pieces of ſoft wood or of cork. If the diſproportion between the two be very conſiderable, we muſt employ a cork which fits the neck of the recipient, having a circular hole of proper dimenſions to admit the beak of the retort. The ſame precaution is neceſſary in adapting bent tubes to the necks of bottles in the apparatus repreſented Pl. IV. Fig. 1. and others of a ſimilar nature. Each mouth of each bottle muſt be fitted with a cork, having a hole made with a round file of a proper ſize for containing the tube. And, when one mouth is intended to admit two or more tubes, which frequently happens when we have not a ſufficient number of bottles with two or three necks, we muſt uſe a cork with two or three holes, Pl. IV. Fig. 8.

When the whole apparatus is thus ſolidly joined, ſo that no part can play upon another, we begin to lute. The lute is ſoftened by kneading and rolling it between the fingers, with the aſſiſtance of heat, if neceſſary. It is rolled into little cylindrical pieces, and applied to the junctures, taking great care to make it apply

apply cloſe, and adhere firmly, in every part; a ſecond roll is applied over the firſt, ſo as to paſs it on each ſide, and ſo on till each juncture be ſufficiently covered; after this, the ſlips of bladder, or of linen, as above directed, muſt be carefully applied over all. Though this operation may appear extremely ſimple, yet it requires peculiar delicacy and management; great care muſt be taken not to diſturb one juncture whilſt luting another, and more eſpecially when applying the fillets and ligatures.

Before beginning any experiment, the cloſeneſs of the luting ought always to be previouſly tried, either by ſlightly heating the retort A, Pl. IV. Fig. 1, or by blowing in a little air by ſome of the perpendicular tubes *S s s s*; the alteration of preſſure cauſes a change in the level of the liquid in theſe tubes. If the apparatus be accurately luted, this alteration of level will be permanent; whereas, if there be the ſmalleſt opening in any of the junctures, the liquid will very ſoon recover its former level. It muſt always be remembered, that the whole ſucceſs of experiments in modern chemiſtry depends upon the exactneſs of this operation, which therefore requires the utmoſt patience, and moſt attentive accuracy.

It would be of infinite ſervice to enable chemiſts, eſpecially thoſe who are engaged in pneumatic proceſſes, to diſpenſe with the uſe of lutes, or at leaſt to diminiſh the number neceſſary in complicated inſtruments. I once thought of having my apparatus conſtructed ſo as to unite in all its parts by fitting with emery, in the way of bottles with criſtal ſtoppers; but the execution of this plan was extremely difficult. I have ſince thought it preferable to ſubſtitute columns of a few lines of mercury in place of lutes, and have got an apparatus conſtructed upon this principle, which appears capable of very convenient application in a great number of circumſtances.

It conſiſts of a double necked bottle A, Pl. XII. Fig. 12.; the interior neck *bc* communicates with the inſide of the bottle, and the exterior neck or rim *de* leaves an interval between the two necks, forming a deep gutter intended to contain the mercury. The cap or lid of glaſs B enters this gutter, and is properly fitted to it, having notches in its lower edge for the paſſage of the tubes which convey the gas. Theſe tubes, inſtead of entering directly into the bottles as in the ordinary apparatus, have a double bend for making them enter the gutter, as repreſented in Fig. 13. and for making them fit the notches of the cap B; they riſe again from the gutter to enter the inſide of the bottle over the border of the inner mouth. When the tubes are diſpoſed in their proper places, and the cap firmly fitted on, the gutter is filled with mer-

mercury, by which means the bottle is completely excluded from any communication, excepting through the tubes. This apparatus may be very convenient in many operations in which the ſubſtances employed have no action upon Mercury. Pl. XII. Fig. 14. repreſents an apparatus upon this principle properly fitted together.

Mr Seguin, to whoſe active and intelligent aſſiſtance I have been very frequently much indebted, has beſpoken for me, at the glaſs-houſes, ſome retorts hermetically united to their recipients, by which luting will be altogether unneceſſary.

CHAP. VIII.

Of Operations upon Combuſtion and Deflagration.

SECT. I.

Of Combuſtion in general.

COMBUSTION, according to what has been already ſaid in the Firſt Part of this Work, is the decompoſition of oxygen gas produced by a combuſtible body. The oxygen which forms the baſe of this gas is abſorbed by, and enters into, combination with the burning body, while the caloric and light are ſet free. Every combuſtion, therefore, neceſſarily ſuppoſes oxygenation; whereas, on the contrary, every oxygenation does not neceſſarily imply concomitant combuſtion; becauſe combuſtion, properly ſo called, cannot take place without diſengagement of caloric and light. Before combuſtion can take place, it is neceſſary that the baſe of oxygen gas ſhould have greater affinity to the combuſtible body than it has to caloric;

loric; and this elective attraction, to uſe Bergman's expreſſion, can only take place at a certain degree of temperature, which is different for each combuſtible ſubſtance; hence the neceſſity of giving a firſt motion or beginning to every combuſtion by the approach of a heated body. This neceſſity of heating any body we mean to burn depends upon certain conſiderations, which have not hitherto been attended to by any natural philoſopher, for which reaſon I ſhall enlarge a little upon the ſubject in this place.

Nature is at preſent in a ſtate of equilibrium, which cannot have been attained until all the ſpontaneous combuſtions or oxygenations poſſible in the ordinary degrees of temperature had taken place. Hence, no new combuſtions or oxygenations can happen without deſtroying this equilibrium, and raiſing the combuſtible ſubſtances to a ſuperior degree of temperature. To illuſtrate this abſtract view of the matter by example: Let us ſuppoſe the uſual temperature of the earth a little changed, and that it is raiſed only to the degree of boiling water; it is evident, that, in this caſe, phoſphorus, which is combuſtible in a conſiderably lower degree of temperature, would no longer exiſt in nature in its pure and ſimple ſtate, but would always be procured in its acid or oxygenated ſtate, and its radical would become one of the ſubſtances unknown

known to chemiſtry. By gradually increaſing the temperature of the earth the ſame circumſtance would ſucceſſively happen to all the bodies capable of combuſtion; and, at laſt, every poſſible combuſtion having taken place, there would no longer exiſt any combuſtible body whatever, as every ſubſtance ſuſceptible of that operation would be oxygenated, and conſequently incombuſtible.

There cannot therefore exiſt, ſo far as relates to us, any combuſtible body, except ſuch as are incombuſtible in the ordinary temperatures of the earth ; or, what is the ſame thing, in other words, that it is eſſential to the nature of every combuſtible body not to poſſeſs the property of combuſtion, unleſs heated, or raiſed to the degree of temperature at which its combuſtion naturally takes place. When this degree is once produced, combuſtion commences, and the caloric which is diſengaged by the decompoſition of the oxygen gas keeps up the temperature neceſſary for continuing combuſtion. When this is not the caſe, that is, when the diſengaged caloric is inſufficient for keeping up the neceſſary temperature, the combuſtion ceaſes : This circumſtance is expreſſed in common language by ſaying, that a body burns ill, or with difficulty.

Although combuſtion poſſeſſes ſome circumſtances in common with diſtillation, eſpecially with the compound kind of that operation, they differ in a very material point. In diſtillation there is a ſeparation of one part of the elements of the ſubſtance from each other, and a combination of theſe, in a new order, occaſioned by the affinities which take place in the increaſed temperature produced during diſtillation: This likewiſe happens in combuſtion, but with this farther circumſtance, that a new element, not originally in the body, is brought into action; oxygen is added to the ſubſtance ſubmitted to the operation, and caloric is diſengaged.

The neceſſity of employing oxygen in the ſtate of gas in all experiments with combuſtion, and the rigorous determination of the quantities employed, render this kind of operations peculiarly troubleſome. As almoſt all the products of combuſtion are diſengaged in the ſtate of gas, it is ſtill more difficult to retain them than even thoſe furniſhed during compound diſtillation; hence this precaution was entirely neglected by the ancient chemiſts; and this ſet of experiments excluſively belong to modern chemiſtry.

Having thus pointed out, in a general way, the objects to be had in view in experiments upon combuſtion, I proceed, in the following ſections of this chapter, to deſcribe the different inſtruments I have uſed with this view. The following arrangement is formed, not upon the nature of the combuſtible bodies, but upon that of the inſtruments neceſſary for combuſtion.

SECT. II.

Of the Combuſtion of Phoſphorus.

In theſe combuſtions we begin by filling a jar, capable at leaſt of holding ſix pints, with oxygen gas in the water apparatus, Pl. V. Fig. 1.; when it is perfectly full, ſo that the gas begins to flow out below, the jar, A, is carried to the mercury apparatus, Pl. IV. Fig. 3. We then dry the ſurface of the mercury, both within and without the jar, by means of blotting-paper, taking care to keep the paper for ſome time entirely immerſed in the mercury before it is introduced under the jar, leſt we let in any common air, which ſticks very obſtinately to the ſurface of the paper. The body to be ſubmitted to combuſtion, being firſt very accurately weighed in nice ſcales, is placed in a ſmall flat ſhallow diſh, D, of iron or porcelain; this is covered by the larger cup P, which ſerves the office of a diving bell, and the whole is paſſed through the mercury into the jar, after which the larger cup is retired. The difficulty of paſſing the materials of combuſtion in this manner through

through the mercury may be avoided by raiſing one of the ſides of the jar, A, for a moment, and ſlipping in the little cup, D, with the combuſtible body as quickly as poſſible. In this manner of operating, a ſmall quantity of common air gets into the jar, but it is ſo very inconſiderable as not to injure either the progreſs or accuracy of the experiment in any ſenſible degree.

When the cup, D, is introduced under the jar, we ſuck out a part of the oxygen gas, ſo as to raiſe the mercury to EF, as formerly directed, Part I. Chap. V. otherwiſe, when the combuſtible body is ſet on fire, the gas becoming dilated would be in part forced out, and we ſhould no longer be able to make any accurate calculation of the quantities before and after the experiment. A very convenient mode of drawing out the air is by means of an air-pump ſyringe adapted to the ſyphon, GHI, by which the mercury may be raiſed to any degree under twenty-eight inches. Very inflammable bodies, as phoſphorus, are ſet on fire by means of the crooked iron wire, MN, Pl. IV. Fig. 16. made red hot, and paſſed quickly through the mercury. Such as are leſs eaſily ſet on fire have a ſmall portion of tinder, upon which a minute particle of phoſphorus is fixed, laid upon them before uſing the red hot iron.

In the firſt moment of combuſtion the air, being heated, rarifies, and the mercury deſcends; but when, as in combuſtions of phoſphorus and iron, no elaſtic fluid is formed, abſorption becomes preſently very ſenſible, and the mercury riſes high into the jar. Great attention muſt be uſed not to burn too large a quantity of any ſubſtance in a given quantity of gas, otherwiſe, towards the end of the experiment, the cup would approach ſo near the top of the jar as to endanger breaking it by the great heat produced, and the ſudden refrigeration from the cold mercury. For the methods of meaſuring the volume of the gaſſes, and for correcting the meaſures according to the heighth of the barometer and thermometer, &c. ſee Chap. II. Sect. V. and VI. of this part.

The above proceſs anſwers very well for burning all the concrete ſubſtances, and even for the fixed oils: Theſe laſt are burnt in lamps under the jar, and are readily ſet on fire by means of tinder, phoſphorus, and hot iron. But it is dangerous for ſubſtances ſuſceptible of evaporating in a moderate heat, ſuch as ether, alkohol, and the eſſential oils; theſe ſubſtances diſſolve in conſiderable quantity in oxygen gas; and, when ſet on fire, a dangerous and ſudden exploſion takes place, which carries up the jar to a great height, and daſhes it in a thouſand pieces. From two ſuch exploſions ſome of the members

members of the Academy and myſelf eſcaped very narrowly. Beſides, though this manner of operating is ſufficient for determining pretty accurately the quantity of oxygen gas abſorbed, and of carbonic acid produced, as water is likewiſe formed in all experiments upon vegetable and animal matters which contain an exceſs of hydrogen, this apparatus can neither collect it nor determine its quantity. The experiment with phoſphorus is even incomplete in this way, as it is impoſſible to demonſtrate that the weight of the phoſphoric acid produced is equal to the ſum of the weights of the phoſphorus burnt and oxygen gas abſorbed during the proceſs. I have been therefore obliged to vary the inſtruments according to circumſtances, and to employ ſeveral of different kinds, which I ſhall deſcribe in their order, beginning with that uſed for burning phoſphorus.

Take a large balloon, A, Pl. IV. Fig. 4. of criſtal or white glaſs, with an opening, EF, about two inches and a half, or three inches, diameter, to which a cap of braſs is accurately fitted with emery, and which has two holes for the paſſage of the tubes *xxx*, *yyy*. Before ſhutting the balloon with its cover, place within it the ſtand, BC, ſupporting the cup of porcelain, D, which contains the phoſphorus. Then lute on the cap with fat lute, and allow it to dry for ſome days, and weigh the whole accurately; after

after this exhauſt the balloon by means of an air-pump connected with the tube *x x x*, and fill it with oxygen gas by the tube *y y y*, from the gazometer, Pl. VIII. Fig. 1. deſcribed Chap. II. Sect. II. of this part. The phoſphorus is then ſet on fire by means of a burning-glaſs, and is allowed to burn till the cloud of concrete phoſphoric acid ſtops the combuſtion, oxygen gas being continually ſupplied from the gazometer. When the apparatus has cooled, it is weighed and unluted; the tare of the inſtrument being allowed, the weight is that of the phoſphoric acid contained. It is proper, for greater accuracy, to examine the air or gas contained in the balloon after combuſtion, as it may happen to be ſomewhat heavier or lighter than common air; and this difference of weight muſt be taken into account in the calculations upon the reſults of the experiment.

SECT. III.

Of the Combuſtion of Charcoal.

The apparatus I have employed for this proceſs conſiſts of a ſmall conical furnace of hammered copper, repreſented in perſpective, Pl. XII. Fig. 9. and internally diſplayed Fig. 11. It is divided

divided into the furnace, ABC, where the charcoal is burnt, the grate, *de*, and the aſh-hole, F; the tube, GH, in the middle of the dome of the furnace ſerves to introduce the charcoal; and as a chimney for carrying off the air which has ſerved for combuſtion. Through the tube, *lmn*, which communicates with the gazometer, the hydrogen gas, or air, intended for ſupporting the combuſtion, is conveyed into the aſh-hole, F, whence it is forced, by the application of preſſure to the gazometer, to paſs through the grate, *de*, and to blow upon the burning charcoal placed immediately above.

Oxygen gas, which forms $\frac{28}{100}$ of atmoſpheric air, is changed into carbonic acid gas during combuſtion with charcoal, whilſt the azotic gas of the air is not altered at all. Hence, after the combuſtion of charcoal in atmoſpheric air, a mixture of carbonic acid gas and azotic gas muſt remain; to allow this mixture to paſs off, the tube, *op*, is adapted to the chimney, GH, by means of a ſcrew at G, and conveys the gas into bottles half filled with ſolution of cauſtic potaſh. The carbonic acid gas is abſorbed by the alkali, and the azotic gas is conveyed into a ſecond gazometer, where its quantity is aſcertained.

The weight of the furnace, ABC, is firſt accurately determined, then introduce the tube RS, of known weight, by the chimney, GH, till

till its, lower end S, reſts upon the grate, *de*, which it occupies entirely; in the next place, fill the furnace with charcoal, and weigh the whole again, to know the exact quantity of charcoal ſubmitted to experiment. The furnace is now put in its place, the tube, *l m n*, is ſcrewed to that which communicates with the gazometer, and the tube, *op*, to that which communicates with the bottles of alkaline ſolution. Every thing being in readineſs, the ſtopcock of the gazometer is opened, a ſmall piece of burning charcoal is thrown into the tube, RS, which is inſtantly withdrawn, and the tube, *o p*, is ſcrewed to the chimney, GH. The little piece of charcoal falls upon the grate, and in this manner gets below the whole charcoal, and is kept on fire by the ſtream of air from the gazometer. To be certain that the combuſtion is begun, and goes on properly, the tube, *q r s*, is fixed to the furnace, having a piece of glaſs cemented to its upper extremity, *s*, through which we can ſee if the charcoal be on fire.

I neglected to obſerve above, that the furnace, and its appendages, are plunged in water in the ciſtern, TVXY, Fig. 11. Pl. XII. to which ice may be added to moderate the heat, if neceſſary; though the heat is by no means very conſiderable, as there is no air but what comes from the gazometer, and no more of the charcoal burns

burns at one time than what is immediately over the grate.

As one piece of charcoal is conſumed another falls down into its place, in conſequence of the declivity of the ſides of the furnace; this gets into the ſtream of air from the grate, *de*, and is burnt; and ſo on, ſucceſſively, till the whole charcoal is conſumed. The air which has ſerved the purpoſe of the combuſtion paſſes through the maſs of charcoal, and is forced by the preſſure of the gazometer to eſcape through the tube, *op*, and to paſs through the bottles of alkaline ſolution.

This experiment furniſhes all the neceſſary data for a complete analyſis of atmoſpheric air and of charcoal. We know the weight of charcoal conſumed; the gazometer gives us the meaſure of the air employed; the quantity and quality of gas remaining after combuſtion may be determined, as it is received, either in another gazometer, or in jars, in a pneumato-chemical apparatus; the weight of aſhes remaining in the aſh-hole is readily aſcertained; and, finally, the additional weight acquired by the bottles of alkaline ſolution gives the exact quantity of carbonic acid formed during the proceſs. By this experiment we may likewiſe determine, with ſufficient accuracy, the proportions in which charcoal and oxygen enter into the compoſition of carbonic acid.

In a future memoir I ſhall give an account to the Academy of a ſeries of experiments I have undertaken, with this inſtrument, upon all the vegetable and animal charcoals. By ſome very ſlight alterations, this machine may be made to anſwer for obſerving the principal phenomena of reſpiration.

SECT. IV.

Of the Combuſtion of Oils.

Oils are more compound in their nature than charcoal, being formed by the combination of at leaſt two elements, charcoal and hydrogen; of courſe, after their combuſtion in common air, water, carbonic acid gas, and azotic gas, remain. Hence the apparatus employed for their combuſtion requires to be adapted for collecting theſe three products, and is conſequently more complicated than the charcoal furnace.

The apparatus I employ for this purpoſe is compoſed of a large jar or pitcher A, Pl. XII. Fig. 4. ſurrounded at its upper edge by a rim of iron properly cemented at DE, and receding from the jar at BC, ſo as to leave a furrow or gutter *xx*, between it and the outſide of the jar, ſomewhat

ſomewhat more than two inches deep. The cover or lid of the jar, Fig. 5. is likewiſe ſurrounded by an iron rim *f g*, which adjuſts into the gutter *x x*, Fig. 4. which being filled with mercury, has the effect of cloſing the jar hermetically in an inſtant, without uſing any lute; and, as the gutter will hold about two inches of mercury, the air in the jar may be made to ſuſtain the preſſure of more than two feet of water, without danger of its eſcaping.

The lid has four holes, T *h i k*, for the paſſage of an equal number of tubes. The opening T is furniſhed with a leather box, through which paſſes the rod, Fig. 3. intended for raiſing and lowering the wick of the lamp, as will be afterwards directed. The three other holes are intended for the paſſage of three ſeveral tubes, one of which conveys the oil to the lamp, a ſecond conveys air for keeping up the combuſtion, and the third carries off the air, after it has ſerved for combuſtion. The lamp in which the oil is burnt is repreſented Fig. 2; *a* is the reſervoir of oil, having a funnel by which it is filled; *b c d e f g h* is a ſyphon which conveys the oil to the lamp 11; 7, 8, 9, 10, is the tube which conveys the air for combuſtion from the gazometer to the ſame lamp. The tube *b c* is formed externally, at its lower end *b*, into a male ſcrew, which turns in a female ſcrew in the lid of the reſervoir of oil *a*; ſo that, by turning the

the reſervoir one way or the other, it is made to riſe or fall, by which the oil is kept at the neceſſary level.

When the ſyphon is to be filled, and the communication formed between the reſervoir of oil and the lamp, the ſtop-cock *c* is ſhut, and that at *e* opened, oil is poured in by the opening *f* at the top of the ſyphon, till it riſes within three or four lines of the upper edge of the lamp, the ſtop-cock *k* is then ſhut, and that at *c* opened; the oil is then poured in at *f*, till the branch *b c d* of the ſyphon is filled, and then the ſtop-cock *e* is cloſed. The two branches of the ſyphon being now completely filled, a communication is fully eſtabliſhed between the reſervoir and the lamp.

In Pl. XII. Fig. 1. all the parts of the lamp 11, Fig. 2. are repreſented magnified, to ſhow them diſtinctly. The tube *i k* carries the oil from the reſervoir to the cavity *a a a a*, which contains the wick; the tube 9, 10, brings the air from the gazometer for keeping up the combuſtion; this air ſpreads through the cavity *d d d d*, and, by means of the paſſages *c c c c* and *b b b b*, is diſtributed on each ſide of the wick, after the principles of the lamps conſtructed by Argand, Quinquet, and Lange.

To render the whole of this complicated apparatus more eaſily underſtood, and that its deſcription may make all others of the ſame kind more

more readily followed, it is repreſented, completely connected together for uſe, in Pl. XI. The gazometer P furniſhes air for the combuſtion by the tube and ſtop-cock 1, 2; the tube 2, 3, communicates with a ſecond gazometer, which is filled whilſt the firſt one is emptying during the proceſs, that there may be no interruption to the combuſtion; 4, 5, is a tube of glaſs filled with deliqueſcent ſalts, for drying the air as much as poſſible in its paſſage; and the weight of this tube and its contained ſalts, at the beginning of the experiment, being known, it is eaſy to determine the quantity of water abſorbed by them from the air. From this deliqueſcent tube the air is conducted through the pipe 5, 6, 7, 8, 9, 10, to the lamp 11, where it ſpreads on both ſides of the wick, as before deſcribed, and feeds the flame. One part of this air, which ſerves to keep up the combuſtion of the oil, forms carbonic acid gas and water, by oxygenating its elements. Part of this water condenſes upon the ſides of the pitcher A, and another part is held in ſolution in the air by means of caloric furniſhed by the combuſtion. This air is forced by the compreſſion of the gazometer to paſs through the tube 12, 13, 14, 15, into the bottle 16, and the worm 17, 18, where the water is fully condenſed from the refrigeration of the air; and, if any water ſtill remains

mains in ſolution, it is abſorbed by deliqueſcent ſalts contained in the tube 19, 20.

All theſe precautions are ſolely intended for collecting and determining the quantity of water formed during the experiment; the carbonic acid and azotic gas remains to be aſcertained. The former is abſorbed by cauſtic alkaline ſolution in the bottles 22 and 25. I have only repreſented two of theſe in the figure; but nine at leaſt are requiſite; and the laſt of the ſeries may be half filled with lime-water, which is the moſt certain reagent for indicating the preſence of carbonic acid; if the lime-water is not rendered turbid, we may be certain that no ſenſible quantity of that acid remains in the air.

The reſt of the air which has ſerved for combuſtion, and which chiefly conſiſts of azotic gas, though ſtill mixed with a conſiderable portion of oxygen gas, which has eſcaped unchanged from the combuſtion, is carried through a third tube 28, 29, of deliqueſcent ſalts, to deprive it of any moiſture it may have acquired in the bottles of alkaline ſolution and lime-water, and from thence by the tube 29, 30, into a gazometer, where its quantity is aſcertained. Small eſſays are then taken from it, which are expoſed to a ſolution of ſulphuret of potaſh, to aſcertain the proportions of oxygen and azotic gas it contains.

In

In the combuſtion of oils the wick becomes charred at laſt, and obſtructs the riſe of the oil; beſides, if we raiſe the wick above a certain height, more oil riſes through its capillary tubes than the ſtream of air is capable of conſuming, and ſmoke is produced. Hence it is neceſſary to be able to lengthen or ſhorten the wick without opening the apparatus; this is accompliſhed by means of the rod 31, 32, 33, 34, which paſſes through a leather-box, and is connected with the ſupport of the wick; and that the motion of this rod, and conſequently of the wick, may be regulated with the utmoſt ſmoothneſs and facility; it is moved at pleaſure by a pinnion which plays in a toothed rack. The rod, with its appendages, are repreſented Pl. XII. Fig. 3. It appeared to me, that the combuſtion would be aſſiſted by ſurrounding the flame of the lamp with a ſmall glaſs jar open at both ends, as repreſented in its place in Pl. XI.

I ſhall not enter into a more detailed deſcription of the conſtruction of this apparatus, which is ſtill capable of being altered and modified in many reſpects, but ſhall only add, that when it is to be uſed in experiment, the lamp and reſervoir with the contained oil muſt be accurately weighed, after which it is placed as before directed, and lighted; having then formed the connection between the air in the gazometer and the lamp, the external jar A, Pl. XI. is fix-

ed

ed over all, and ſecured by means of the board BC and two rods of iron which connect this board with the lid, and are ſcrewed to it. A ſmall quantity of oil is burnt while the jar is adjuſting to the lid, and the product of that combuſtion is loſt; there is likewiſe a ſmall portion of air from the gazometer loſt at the ſame time. Both of theſe are of very inconſiderable conſequence in extenſive experiments, and they are even capable of being valued in our calculation of the reſults.

In a particular memoir, I ſhall give an account to the Academy of the difficulties inſeparable from this kind of experiments: Theſe are ſo inſurmountable and troubleſome, that I have not hitherto been able to obtain any rigorous determination of the quantities of the products. I have ſufficient proof, however, that the fixed oils are entirely reſolved during combuſtion into water and carbonic acid gas, and conſequently that they are compoſed of hydrogen and charcoal; but I have no certain knowledge reſpecting the proportions of theſe ingredients.

SECT. V.

Of the Combuſtion of Alkohol.

The combuſtion of alkohol may be very readily performed in the apparatus already deſcribed for the combuſtion of charcoal and phoſphorus. A lamp filled with alkohol is placed under the jar A, Pl. IV. Fig. 3. a ſmall morſel of phoſphorus is placed upon the wick of the lamp, which is ſet on fire by means of the hot iron, as before directed. This proceſs is, however, liable to conſiderable inconveniency; it is dangerous to make uſe of oxygen gas at the beginning of the experiment for fear of deflagration, which is even liable to happen when common air is employed. An inſtance of this had very near proved fatal to myſelf, in preſence of ſome members of the Academy. Inſtead of preparing the experiment, as uſual, at the time it was to be performed, I had diſpoſed every thing in order the evening before; the atmoſpheric air of the jar had thereby ſufficient time to diſſolve a good deal of the alkohol; and this evaporation had even been conſiderably promoted by the height of the column of mercury, which I had raiſed to EF, Pl. IV. Fig. 3. The moment I attempted ed to ſet the little morſel of phoſphorus on fire by means of the red hot iron, a violent exploſion took place, which threw the jar with great violence againſt the floor of the laboratory, and daſhed it in a thouſand pieces.

Hence we can only operate upon very ſmall quantities, ſuch as ten or twelve grains of alkohol, in this manner; and the errors which may be committed in experiments upon ſuch ſmall quantities prevents our placing any confidence in their reſults. I endeavoured to prolong the combuſtion, in the experiments contained in the Memoirs of the Academy for 1784, p. 593. by lighting the alkohol firſt in common air, and furniſhing oxygen gas afterwards to the jar, in proportion as it conſumed; but the carbonic acid gas produced by the proceſs became a great hinderance to the combuſtion, the more ſo that alkohol is but difficultly combuſtible, eſpecially in worſe than common air; ſo that even in this way very ſmall quantities only could be burnt.

Perhaps this combuſtion might ſucceed better in the oil apparatus, Pl. XI.; but I have not hitherto ventured to try it. The jar A in which the combuſtion is performed is near 1400 cubical inches in dimenſion; and, were an exploſion to take place in ſuch a veſſel, its conſequences would be very terrible, and very difficult to guard againſt. I have not, however, deſpaired of making the attempt.

From

From all theſe difficulties, I have been hitherto obliged to confine myſelf to experiments upon very ſmall quantities of alkohol, or at leaſt to combuſtions made in open veſſels, ſuch as that repreſented in Pl. IX. Fig. 5. which will be deſcribed in Section VII. of this chapter. If I am ever able to remove theſe difficulties, I ſhall reſume this inveſtigation.

SECT. VI.

Of the Combuſtion of Ether.

Tho' the combuſtion of ether in cloſe veſſels does not preſent the ſame difficulties as that of alkohol, yet it involves ſome of a different kind, not more eaſily overcome, and which ſtill prevent the progreſs of my experiments. I endeavoured to profit by the property which ether poſſeſſes of diſſolving in atmoſpheric air, and rendering it inflammable without exploſion. For this purpoſe, I conſtructed the reſervoir of ether *a b c d*, Plate XII. Fig. 8. to which air is brought from the gazometer by the tube 1, 2, 3, 4. This air ſpreads, in the firſt place, in the double lid *ac* of the reſervoir, from which it paſſes through ſeven tubes *ef*, *gh*, *ik*, &c. which deſcend to the bottom of the ether, and it is forced

forced by the preſſure of the gazometer to boil up through the ether in the reſervoir. We may replace the ether in this firſt reſervoir, in proportion as it is diſſolved and carried off by the air, by means of the ſupplementary reſervoir E, connected by a braſs tube fifteen or eighteen inches long, and ſhut by a ſtop-cock. This length of the connecting tube is to enable the deſcending ether to overcome the reſiſtance occaſioned by the preſſure of the air from the gazometer.

The air, thus loaded with vapours of ether, is conducted by the tube 5, 6, 7, 8, 9, to the jar A, into which it is allowed to eſcape through a capillary opening, at the extremity of which it is ſet on fire. The air, when it has ſerved the purpoſe of combuſtion, paſſes through the bottle 16, Pl. XI. the worm 17, 18, and the deliqueſcent tube 19, 20, after which it paſſes through the alkaline bottles; in theſe its carbonic acid gas is abſorbed, the water formed during the experiment having been previouſly depoſited in the former parts of the apparatus.

When I cauſed conſtruct this apparatus, I ſuppoſed that the combination of atmoſpheric air and ether formed in the reſervoir *a b c d*, Pl. XII. Fig. 8. was in proper proportion for ſupporting combuſtion; but in this I was miſtaken; for there is a very conſiderable quantity of exceſs of ether; ſo that an additional quantity of atmoſpheric

ſpheric air is neceſſary to enable it to burn fully. Hence a lamp conſtructed upon theſe principles will burn in common air, which furniſhes the quantity of oxygen neceſſary for combuſtion, but will not burn in cloſe veſſels in which the air is not renewed. From this circumſtance, my ether lamp went out ſoon after being lighted and ſhut up in the jar A, Pl. XII. Fig. 8. To remedy this defect, I endeavoured to bring atmoſpheric air to the lamp by ths lateral tube 10, 11, 12, 13, 14, 15, which I diſtributed circularly round the flame; but the flame is ſo exceedingly rare, that it is blown out by the gentleſt poſſible ſtream of air, ſo that I have not hitherto ſucceeded in burning ether. I do not, however, deſpair of being able to accompliſh it by means of ſome changes I am about to have made upon this apparatus.

SECT. VII.

Of the Combuſtion of Hydrogen Gas, and the Formation of Water.

In the formation of water, two ſubſtances, hydrogen and oxygen, which are both in the aëriform ſtate before combuſtion, are tranſformed into liquid or water by the operation. This

This experiment would be very eaſy, and would require very ſimple inſtruments, if it were poſſible to procure the two gaſſes perfectly pure, ſo that they might burn without any reſiduum. We might, in that caſe, operate in very ſmall veſſels, and, by continually furniſhing the two gaſſes in proper proportions, might continue the combuſtion indefinitely. But, hitherto, chemiſts have only employed oxygen gas, mixed with azotic gas; from which circumſtance, they have only been able to keep up the combuſtion of hydrogen gas for a very limited time in cloſe veſſels, becauſe, as the reſiduum of azotic gas is continually increaſing, the air becomes at laſt ſo much contaminated, that the flame weakens and goes out. This inconvenience is ſo much the greater in proportion as the oxygen gas employed is leſs pure. From this circumſtance, we muſt either be ſatisfied with operating upon ſmall quantities, or muſt exhauſt the veſſels at intervals, to get rid of the reſiduum of azotic gas; but, in this caſe, a portion of the water formed during the experiment is evaporated by the exhauſtion; and the reſulting error is the more dangerous to the accuracy of the proceſs, that we have no certain means of valuing it.

Theſe conſiderations make me deſirous to repeat the principal experiments of pneumatic chemiſtry with oxygen gas entirely free from any admixture of azotic gas; and this may be procured from oxygenated muriat of potaſh. The oxygen gas extracted from this ſalt does not appear to contain azote, unleſs accidentally, ſo that, by proper precautions, it may be obtained perfectly pure. In the mean time, the apparatus employed by Mr Meuſnier and me for the combuſtion of hydrogen gas, which is deſcribed in the experiment for recompoſition of water, Part I. Chap. VIII. and need not be here repeated, will anſwer the purpoſe; when pure gaſſes are procured, this apparatus will require no alterations, except that the capacity of the veſſels may then be diminiſhed. See Pl. IV. Fig. 5.

The combuſtion, when once begun, continues for a conſiderable time, but weakens gradually, in proportion as the quantity of azotic gas remaining from the combuſtion increaſes, till at laſt the azotic gas is in ſuch over proportion that the combuſtion can no longer be ſupported, and the flame goes out. This ſpontaneous extinction muſt be prevented, becauſe, as the hydrogen gas is preſſed upon in its reſervoir, by an inch and a half of water, whilſt the oxygen gas ſuffers a preſſure only of three lines, a mixture of the two would take place in the balloon, which would at laſt be forced by the ſuperior preſſure into the reſervoir of oxygen gas. Wherefore the combuſtion muſt be ſtopped,

ped, by ſhutting the ſtop-cock of the tube *d*D*d* whenever the flame grows very feeble; for which purpoſe it muſt be attentively watched.

There is another apparatus for combuſtion, which, though we cannot with it perform experiments with the ſame ſcrupulous exactneſs as with the preceding inſtruments, gives very ſtriking reſults that are extremely proper to be ſhewn in courſes of philoſophical chemiſtry. It conſiſts of a worm EF, Pl. IX. Fig. 5. contained in a metallic cooller ABCD. To the upper part of this worm E, the chimney GH is fixed, which is compoſed of two tubes, the inner of which is a continuation of the worm, and the outer one is a caſe of tin-plate, which ſurrounds it at about an inch diſtance, and the interval is filled up with ſand. At the inferior extremity K of the inner tube, a glaſs tube is fixed, to which we adopt the Argand lamp LM for burning alkohol, &c.

Things being thus diſpoſed, and the lamp being filled with a determinate quantity of alkohol, it is ſet on fire; the water which is formed during the combuſtion riſes in the chimney KE, and being condenſed in the worm, runs out at its extremity F into the bottle P. The double tube of the chimney, filled with ſand in the interſtice, is to prevent the tube from cooling in its upper part, and condenſing the water; o-

therwiſe,

therwiſe, it would fall back in the tube, and we ſhould not be able to aſcertain its quantity, and beſides it might fall in drops upon the wick, and extinguiſh the flame. The intention of this conſtruction, is to keep the chimney always hot, and the worm always cool, that the water may be preſerved in the ſtate of vapour whilſt riſing, and may be condenſed immediately upon getting into the deſcending part of the apparatus. By this inſtrument, which was contrived by Mr Meuſnier, and which is deſcribed by me in the Memoirs of the Academy for 1784, p. 593. we may, with attention to keep the worm always cold, collect nearly ſeventeen ounces of water from the combuſtion of ſixteen ounces of alkohol.

SECT. VIII.

Of the Oxydation of Metals.

The term *oxydation* or *calcination* is chiefly uſed to ſignify the proceſs by which metals expoſed to a certain degree of heat are converted into oxyds, by abſorbing oxygen from the air. This combination takes place in conſequence of oxygen poſſeſſing a greater affinity to metals, at a certain temperature, than to caloric, which becomes diſengaged in its free ſtate ; but, as this diſengagement, when made in common air, is ſlow and progreſſive, it is ſcarcely evident to the ſenſes. It is quite otherwiſe, however, when oxydation takes place in oxygen gas ; for, being produced with much greater rapidity, it is generally accompanied with heat and light, ſo as evidently to ſhow that metallic ſubſtances are real combuſtible bodies.

All the metals have not the ſame degree of affinity to oxygen. Gold, ſilver, and platina, for inſtance, are incapable of taking it away from its combination with caloric, even in the greateſt known heat ; whereas the other metals abſorb it in a larger or ſmaller quantity, until the affinities of the metal to oxygen, and of the latter to caloric, are in exact equilibrium. Indeed, this ſtate of equilibrium of affinities may be aſſumed as a general law of nature in all combinations.

In all operations of this nature, the oxydation of metals is accelerated by giving free acceſs to the air ; it is ſometimes much aſſiſted by joining the action of a bellows, which directs a ſtream of air over the ſurface of the metal. This proceſs becomes greatly more rapid if a ſtream of oxygen gas be uſed, which is readily done by means of the gazometer formerly deſcribed. The metal, in this caſe, throws out a brilliant ſlame, and the oxydation is very quickly ly accompliſhed; but this method can only be uſed in very confined experiments, on account of the expence of procuring oxygen gas. In the eſſay of ores, and in all the common operations of the laboratory, the calcination or oxydation of metals is uſually performed in a diſh of baked clay, Pl. IV. Fig. 6. commonly called a *roaſting teſt*, placed in a ſtrong furnace. The ſubſtances to be oxydated are frequently ſtirred, on purpoſe to preſent freſh ſurfaces to the air.

Whenever this operation is performed upon a metal which is not volatile, and from which nothing flies off into the ſurrounding air during the proceſs, the metal acquires additional weight; but the cauſe of this increaſed weight during oxydation could never have been diſcovered by means of experiments performed in free air; and it is only ſince theſe operations have been performed in cloſe veſſels, and in determinate quantities of air, that any juſt conjectures have been formed concerning the cauſe of this phenomenon. The firſt method for this purpoſe is due to Dr Prieſtley, who expoſes the metal to be calcined in a porcelain cup N, Pl. IV. Fig. 11. placed upon the ſtand IK, under a jar A, in the baſon BCDE, full of water; the water is made to riſe up to GH, by ſucking out the air with a ſyphon, and the focus of a burning glaſs is made to fall upon the metal. In a few minutes the oxydation takes place, a a part of the oxygen contained in the air combines with the metal, and a proportional diminution of the volume of air is produced; what remains is nothing more than azotic gas, ſtill however mixed with a ſmall quantity of oxygen gas. I have given an account of a ſeries of experiments made with this apparatus in my Phyſical and Chemical Eſſays, firſt publiſhed in 1773. Mercury may be uſed inſtead of water in this experiment, whereby the reſults are rendered ſtill more concluſive.

Another proceſs for this purpoſe was invented by Mr Boyle, and of which I gave an account in the Memoirs of the Academy for 1774, p. 351. The metal is introduced into a retort, Pl. III. Fig. 20. the beak of which is hermetically ſealed; the metal is then oxydated by means of heat applied with great precaution. The weight of the veſſel, and its contained ſubſtances, is not at all changed by this proceſs, until the extremity of the neck of the retort is broken; but, when that is done, the external air ruſhes in with a hiſſing noiſe. This operation is attended with danger, unleſs a part of the air is driven out of the retort, by means of heat, before it is hermetically ſealed, as otherwiſe the retort would be apt to burſt by the dilation of the air when placed in the furnace. The quantity of air driven out may be received under a jar in the pneumato-chemical apparatus,

tus, by which its quantity, and that of the air remaining in the retort, is aſcertained. I have not multiplied my experiments upon oxydation of metals ſo much as I could have wiſhed ; neither have I obtained ſatisfactory reſults with any metal except tin. It is much to be wiſhed that ſome perſon would undertake a ſeries of experiments upon oxydation of metals in the ſeveral gaſſes ; the ſubject is important, and would fully repay any trouble which this kind of experiment might occaſion.

As all the oxyds of mercury are capable of revivifying without addition, and reſtore the oxygen gas they had before abſorbed, this ſeemed to be the moſt proper metal for becoming the ſubject of concluſive experiments upon oxydation. I formerly endeavoured to accompliſh the oxydation of mercury in cloſe veſſels, by filling a retort, containing a ſmall quantity of mercury, with oxygen gas, and adapting a bladder half full of the ſame gas to its beak ; See Pl. IV. Fig. 12. Afterwards, by heating the mercury in the retort for a very long time, I ſucceeded in oxydating a very ſmall portion, ſo as to form a little red oxyd floating upon the ſurface of the running mercury ; but the quantity was ſo ſmall, that the ſmalleſt error committed in the determination of the quantities of oxygen gas before and after the operation muſt have thrown very great uncertainty upon the reſults

reſults of the experiment. I was, beſides, diſſatisfied with this proceſs, and not without cauſe, leſt any air might have eſcaped through the pores of the bladder, more eſpecially as it becomes ſhrivelled by the heat of the furnace, unleſs covered over with cloths kept conſtantly wet.

This experiment is performed with more certainty in the apparatus deſcribed in the Memoirs of the Academy for 1775, p. 580. This conſiſts of a retort, A, Pl. IV. Fig. 2. having a crooked glaſs tube BCDE of ten or twelve lines internal diameter, melted on to its beak, and which is engaged under the bell glaſs FG, ſtanding with its mouth downwards, in a baſon filled with water or mercury. The retort is placed upon the bars of the furnace MMNN, Pl. IV. Fig. 2. or in a ſand bath, and by means of this apparatus we may, in the courſe of ſeveral days, oxydate a ſmall quantity of mercury in common air; the red oxyd floats upon the ſurface, from which it may be collected and revivified, ſo as to compare the quantity of oxygen gas obtained in revivification with the abſorption which took place during oxydation. This kind of experiment can only be performed upon a ſmall ſcale, ſo that no very certain concluſions can be drawn from them *.

The

---

* See an account of this experiment, Part. I. Chap. iii.—A.

The combuſtion of iron in oxygen gas being a true oxydation of that metal, ought to be mentioned in this place. The apparatus employed by Mr Ingenhouſz for this operation is repreſented in Pl. IV. Fig. 17.; but, having already deſcribed it ſufficiently in Chap. III. I ſhall refer the reader to what is ſaid of it in that place. Iron may likewiſe be oxydated by combuſtion in veſſels filled with oxygen gas, in the way already directed for phoſphorus and charcoal. This apparatus is repreſented Pl. IV. Fig. 3. and deſcribed in the fifth chapter of the firſt part of this work. We learn from Mr Ingenhouſz, that all the metals, except gold, ſilver, and mercury, may be burnt or oxydated in the ſame manner, by reducing them into very fine wire, or very thin plates cut into narrow ſlips; theſe are twiſted round with iron-wire, which communicates the property of burning to the other metals.

Mercury is even difficultly oxydated in free air. In chemical laboratories, this proceſs is uſually carried on in a matraſs A, Pl. IV. Fig. having a very flat body, and a very long neck BC, which veſſel is commonly called *Boyle's hell*. A quantity of mercury is introduced ſufficient to cover the bottom, and it is placed in a ſand-bath, which keeps up a conſtant heat approaching to that of boiling mercury. By continuing this operation with five or ſix ſimilar matraſſes during ſeveral months, and renewing

newing the mercury from time to time, a few ounces of red oxyd are at laſt obtained. The great ſlowneſs and inconvenience of this apparatus ariſes from the air not being ſufficiently renewed; but if, on the other hand, too free a circulation were given to the external air, it would carry off the mercury in ſolution in the ſtate of vapour, ſo that in a few days none would remain in the veſſel.

As, of all the experiments upon the oxydation of metals, thoſe with mercury are the moſt concluſive, it were much to be wiſhed that a ſimple apparatus could be contrived by which this oxydation and its reſults might be demonſtrated in public courſes of chemiſtry. This might, in my opinion, be accompliſhed by methods ſimilar to thoſe I have already deſcribed for the combuſtion of charcoal and the oils; but, from other purſuits, I have not been able hitherto to reſume this kind of experiment.

The oxyd of mercury revives without addition, by being heated to a ſlightly red heat. In this degree of temperature, oxygen has greater affinity to caloric than to mercury, and forms oxygen gas. This is always mixed with a ſmall portion of azotic gas, which indicates that the mercury abſorbs a ſmall portion of this latter gas during oxydation. It almoſt always contains a little carbonic acid gas, which muſt undoubtedly be attributed to the foulneſſes of the

oxyd;

oxyd; theſe are charred by the heat, and convert a part of the oxygen gas into carbonic acid.

If chemiſts were reduced to the neceſſity of procuring all the oxygen gas employed in their experiments from mercury oxydated by heat without addition, or, as it is called, *calcined* or *precipitated* per ſe, the exceſſive dearneſs of that preparation would render experiments, even upon a moderate ſcale, quite impracticable. But mercury may likewiſe be oxydated by means of nitric acid; and in this way we procure a red oxyd, even more pure than that produced by calcination. I have ſometimes prepared this oxyd by diſſolving mercury in nitric acid, evaporating to dryneſs, and calcining the ſalt, either in a retort, or in capſules formed of pieces of broken matraſſes and retorts, in the manner formerly deſcribed; but I have never ſucceeded in making it equally beautiful with what is ſold by the druggiſts, and which is, I believe, brought from Holland. In chooſing this, we ought to prefer what is in ſolid lumps compoſed of ſoft adhering ſcales, as when in powder it is ſometimes adulterated with red oxyd of lead.

To obtain oxygen gas from the red oxyd of mercury, I uſually employ a porcelain retort, having a long glaſs tube adapted to its beak, which is engaged under jars in the water pneumatomato-chemical apparatus, and I place a bottle in the water, at the end of the tube, for receiving the mercury, in proportion as it revives and diſtils over. As the oxygen gas never appears till the retort becomes red, it ſeems to prove the principle eſtabliſhed by Mr Berthollet, that an obſcure heat can never form oxygen gas, and that light is one of its conſtituent elements. We muſt reject the firſt portion of gas which comes over, as being mixed with common air, from what was contained in the retort at the beginning of the experiment; but, even with this precaution, the oxygen gas procured is uſually contaminated with a tenth part of azotic gas, and with a very ſmall portion of carbonic acid gas. This latter is readily got rid of, by making the gas paſs through a ſolution of cauſtic alkali; but we know of no method for ſeparating the azotic gas; its proportions may however be aſcertained, by leaving a known quantity of the oxygen gas contaminated with it for a fortnight, in contact with ſulphuret of ſoda or potaſh, which abſorbs the oxygen gas ſo as to convert the ſulphur into ſulphuric acid, and leaves the azotic gas remaining pure.

We may likewiſe procure oxygen gas from black oxyd of manganeſe or nitrat of potaſh, by expoſing them to a red heat in the apparatus already deſcribed for operating upon red oxyd

oxyd of mercury; only, as it requires ſuch a heat as is at leaſt capable of ſoftening glaſs, we muſt employ retorts of ſtone or of porcelain. But the pureſt and beſt oxygen gas is what is diſengaged from oxygenated muriat of potaſh by ſimple heat. This operation is performed in a glaſs retort, and the gas obtained is perfectly pure, provided that the firſt portions, which are mixed with the common air of the veſſels, be rejected.

CHAP. IX.

Of Deflagration.

I HAVE already ſhown, Part I. Chap. IX. that oxygen does not always part with the whole of the caloric it contained in the ſtate of gas when it enters into combination with other bodies. It carries almoſt the whole of its caloric alongſt with it in entering into the combinations which form nitric acid and oxygenated muriatic acid; ſo that in nitrats, and more eſpecially in oxygenated muriats, the oxygen is, in a certain degree, in the ſtate of oxygen gas, condenſed, and reduced to the ſmalleſt volume it is capable of occupying.

In theſe combinations, the caloric exerts a conſtant action upon the oxygen to bring it back to the ſtate of gas; hence the oxygen adheres but very ſlightly, and the ſmalleſt additional force is capable of ſetting it free; and, when ſuch force is applied, it often recovers the ſtate of gas inſtantaneouſly. This rapid paſſage from the ſolid to the aëriform ſtate is called detonation, or fulmination, becauſe it is uſually accompanied with noiſe and exploſion. Deflagrations are commonly produced by means of combinations of charcoal either with nitre or oxygenated

oxygenated muriat of potaſh; ſometimes, to aſſiſt the inflammation, ſulphur is added; and, upon the juſt proportion of theſe ingredients, and the proper manipulation of the mixture, depends the art of making gun-powder.

As oxygen is changed, by deflagration with charcoal, into carbonic acid, inſtead of oxygen gas, carbonic acid gas is diſengaged, at leaſt when the mixture has been made in juſt proportions. In deflagration with nitre, azotic gas is likewiſe diſengaged, becauſe azote is one of the conſtituent elements of nitric acid.

The ſudden and inſtantaneous diſengagement and expanſion of theſe gaſſes is not, however, ſufficient for explaining all the phenomena of deflagration; becauſe, if this were the ſole operating power, gun-powder would always be ſo much the ſtronger in proportion as the quantity of gas diſengaged in a given time was the more conſiderable, which does not always accord with experiment. I have tried ſome kinds which produced almoſt double the effect of ordinary gun-powder, although they gave out a ſixth part leſs of gas during deflagration. It would appear that the quantity of caloric diſengaged at the moment of detonation contributes conſiderably to the expanſive effects produced; for, although caloric penetrates freely through the pores of every body in nature, it can only do ſo progreſſively, and in a given time; hence, when

when the quantity diſengaged at once is too large to get through the pores of the ſurrounding bodies, it muſt neceſſarily act in the ſame way with ordinary elaſtic fluids, and overturn every thing that oppoſes its paſſage. This muſt, at leaſt in part, take place when gun-powder is ſet on fire in a cannon; as, although the metal is permeable to caloric, the quantity diſengaged at once is too large to find its way through the pores of the metal, it muſt therefore make an effort to eſcape on every ſide; and, as the reſiſtance all around, excepting towards the muzzle, is too great to be overcome, this effort is employed for expelling the bullet.

The caloric produces a ſecond effect, by means of the repulſive force exerted between its particles; it cauſes the gaſſes, diſengaged at the moment of deflagration, to expand with a degree of force proportioned to the temperature produced.

It is very probable that water is decompoſed during the deflagration of gun-powder, and that part of the oxygen furniſhed to the naſcent carbonic acid gas is produced from it. If ſo, a conſiderable quantity of hydrogen gas muſt be diſengaged in the inſtant of deflagration, which expands, and contributes to the force of the exploſion. It may readily be conceived how greatly this circumſtance muſt increaſe the effect of powder, if we conſider that a pint of hydrogen gas weighs only one grain and two thirds; hence a very ſmall quantity in weight muſt occupy a very large ſpace, and it muſt exert a prodigious expanſive force in paſſing from the liquid to the aëriform ſtate of exiſtence.

In the laſt place, as a portion of undecompoſed water is reduced to vapour during the deflagration of gun-powder, and as water, in the ſtate of gas, occupies ſeventeen or eighteen hundred times more ſpace than in its liquid ſtate, this circumſtance muſt likewiſe contribute largely to the exploſive force of the powder.

I have already made a conſiderable ſeries of experiments upon the nature of the elaſtic fluids diſengaged during the deflagration of nitre with charcoal and ſulphur; and have made ſome, likewiſe, with the oxygenated muriat of potaſh. This method of inveſtigation leads to tollerably accurate concluſions with reſpect to the conſtituent elements of theſe ſalts. Some of the principal reſults of theſe experiments, and of the conſequences drawn from them reſpecting the analyſis of nitric acid, are reported in the collection of memoirs preſented to the Academy by foreign philoſophers, vol. xi. p. 625. Since then I have procured more convenient inſtruments, and I intend to repeat theſe experiments upon a larger ſcale, by which I ſhall procure more accurate preciſion in their reſults; the following, however, is the proceſs I have hither-

to

to employed. I would very earneſtly adviſe ſuch as intend to repeat ſome of theſe experiments, to be very much upon their guard in operating upon any mixture which contains nitre, charcoal, and ſulphur, and more eſpecially with thoſe in which oxygenated muriat of potaſh is mixed with theſe two materials.

I make uſe of piſtol barrels, about ſix inches long, and of five or ſix lines diameter, having the touch-hole ſpiked up with an iron nail ſtrongly driven in, and broken in the hole, and a little tin-ſmith's ſolder run in to prevent any poſſible iſſue for the air. Theſe are charged with a mixture of known quantities of nitre and charcoal, or any other mixture capable of deflagration, reduced to an impalpable powder, and formed into a paſte with a moderate quantity of water. Every portion of the materials introduced muſt be rammed down with a rammer nearly of the ſame caliber with the barrel, four or five lines at the muzzle muſt be left empty, and about two inches of quick match are added at the end of the charge. The only difficulty in this experiment, eſpecially when ſulphur is contained in the mixture, is to diſcover the proper degree of moiſtening; for, if the paſte be too much wetted, it will not take fire, and if too dry, the deflagration is apt to become too rapid, and even dangerous.

When

When the experiment is not intended to be rigorouſly exact, we ſet fire to the match, and, when it is juſt about to communicate with the charge, we plunge the piſtol below a large bell-glaſs full of water, in the pneumato-chemical apparatus. The deflagration begins, and continues in the water, and gas is diſengaged with leſs or more rapidity, in proportion as the mixture is more or leſs dry. So long as the deflagration continues, the muzzle of the piſtol muſt be kept ſomewhat inclined downwards, to prevent the water from getting into its barrel. In this manner I have ſometimes collected the gas produced from the deflagration of an ounce and half, or two ounces, of nitre.

In this manner of operating it is impoſſible to determine the quantity of carbonic acid gas diſengaged, becauſe a part of it is abſorbed by the water while paſſing through it; but, when the carbonic acid is abſorbed, the azotic gas remains; and, if it be agitated for a few minutes in cauſtic alkaline ſolution, we obtain it pure, and can eaſily determine its volume and weight. We may even, in this way, acquire a tollerably exact knowledge of the quantity of carbonic acid by repeating the experiment a great many times, and varying the proportions of charcoal, till we find the exact quantity requiſite to deflagrate the whole nitre employed. Hence, by means of the weight of charcoal employed, we determine the weight of oxygen neceſſary for ſaturation, and deduce the quantity of oxygen contained in a given weight of nitre.

I have uſed another proceſs, by which the reſults of this experiment are conſiderably more accurate, which conſiſts in receiving the diſengaged gaſſes in bell-glaſſes filled with mercury. The mercurial apparatus I employ is large enough to contain jars of from twelve to fifteen pints in capacity, which are not very readily managed when full of mercury, and even require to be filled by a particular method. When the jar is placed in the ciſtern of mercury, a glaſs ſyphon is introduced, connected with a ſmall air-pump, by means of which the air is exhauſted, and the mercury riſes ſo as to fill the jar. After this, the gas of the deflagration is made to paſs into the jar in the ſame manner as directed when water is employed.

I muſt again repeat, that this ſpecies of experiment requires to be performed with the greateſt poſſible precautions. I have ſometimes ſeen, when the diſengagement of gas proceeded with too great rapidity, jars filled with more than an hundred and fifty pounds of mercury driven off by the force of the exploſion, and broken to pieces, while the mercury was ſcattered about in great quantities.

When the experiment has ſucceeded, and the gas is collected under the jar, its quantity in general,

general, and the nature and quantities of the ſeveral ſpecies of gaſſes of which the mixture is compoſed, are accurately aſcertained by the methods already pointed out in the ſecond chapter of this part of my work. I have been prevented from putting the laſt hand to the experiments I had begun upon deflagration, from their connection with the objects I am at preſent engaged in; and I am in hopes they will throw conſiderable light upon the operations belonging to the manufacture of gun-powder.

CHAP. X.

Of the Inſtruments neceſſary for Operating upon Bodies in very high Temperatures.

SECT. I.

Of Fuſion.

WE have already ſeen, that, by aqueous ſolution, in which the particles of bodies are ſeparated from each other, neither the ſolvent nor the body held in ſolution are at all decompoſed; ſo that, whenever the cauſe of ſeparation ceaſes, the particles reunite, and the ſaline ſubſtance recovers preciſely the ſame appearance and properties it poſſeſſed before ſolution. Real ſolutions are produced by fire, or by introducing and accumulating a great quantity of caloric between the particles of bodies; and this ſpecies of ſolution in caloric is uſually called *fuſion.*

This operation is commonly performed in veſſels called crucibles, which muſt neceſſarily be be leſs fuſible than the bodies they are intended to contain. Hence, in all ages, chemiſts have been extremely ſolicitous to procure crucibles of very refractory materials, or ſuch as are capable of reſiſting a very high degree of heat. The beſt are made of very pure clay or of porcelain earth; whereas ſuch as are made of clay mixed with calcareous or ſilicious earth are very fuſible. All the crucibles made in the neighbourhood of Paris are of this kind, and conſequently unfit for moſt chemical experiments. The Heſſian crucibles are tolerably good; but the beſt are made of Limoges earth, which ſeems abſolutely infuſible. We have, in France, a great many clays very fit for making crucibles; ſuch, for inſtance, is the kind uſed for making melting pots at the glaſs-manufactory of St Gobin.

Crucibles are made of various forms, according to the operations they are intended to perform. Several of the moſt common kinds are repreſented Pl. VII. Fig. 7. 8. 9. and 10. the one repreſented at Fig. 9. is almoſt ſhut at its mouth.

Though fuſion may often take place without changing the nature of the fuſed body, this operation is frequently employed as a chemical means of decompoſing and recompounding bodies. In this way all the metals are extracted from their ores; and, by this proceſs, they are revivified, moulded, and alloyed with each other. By this proceſs ſand and alkali are combined to form glaſs, and by it likewiſe paſtes, or coloured ſtones, enamels, &c. are formed.

The action of violent fire was much more frequently employed by the ancient chemiſts than it is in modern experiments. Since greater preciſion has been employed in philoſophical reſearches, the *humid* has been preferred to the *dry* method of proceſs, and fuſion is ſeldom had recourſe to until all the other means of analyſis have failed.

SECT. II.

Of Furnaces.

Theſe are inſtruments of moſt univerſal uſe in chemiſtry; and, as the ſucceſs of a great number of experiments depends upon their being well or ill conſtructed, it is of great importance that a laboratory be well provided in this reſpect. A furnace is a kind of hollow cylindrical tower, ſometimes widened above, Pl. XIII. Fig. 1. ABCD, which muſt have at leaſt two lateral openings; one in its upper part F, which is the door of the fire-place, and one below, G, leading to the aſh-hole. Between theſe the furnace

nace is divided by a horizontal grate, intended for ſupporting the fewel, the ſituation of which is marked in the figure by the line HI. Though this be the leaſt complicated of all the chemical furnaces, yet it is applicable to a great number of purpoſes. By it lead, tin, biſmuth, and, in general, every ſubſtance which does not require a very ſtrong fire, may be melted in crucibles; it will ſerve for metallic oxydations, for evaporatory veſſels, and for ſand-baths, as in Pl. III. Fig. 1. and 2. To render it proper for theſe purpoſes, ſeveral notches, *m m m m*, Pl. XIII. Fig. 1. are made in its upper edge, as otherwiſe any pan which might be placed over the fire would ſtop the paſſage of the air, and prevent the fewel from burning. This furnace can only produce a moderate degree of heat, becauſe the quantity of charcoal it is capable of conſuming is limited by the quantity of air which is allowed to paſs through the opening G of the aſh-hole. Its power might be conſiderably augmented by enlarging this opening, but then the great ſtream of air which is convenient for ſome operations might be hurtful in others; wherefore we muſt have furnaces of different forms, conſtructed for different purpoſes, in our laboratories: There ought eſpecially to be ſeveral of the kind now deſcribed of different ſizes.

The reverberatory furnace, Pl. XIII. Fig. 2. is perhaps more neceſſary. This, like the common

mon furnace, is compoſed of the aſh-hole HIKL, the fire-place KLMN, the laboratory MNOP, and the dome RRSS, with its funnel or chimney TTVV; and to this laſt ſeveral additional tubes may be adapted, according to the nature of the different experiments. The retort A is placed in the diviſion called the laboratory, and ſupported by two bars of iron which run acroſs the furnace, and its beak comes out at a round hole in the ſide of the furnace, one half of which is cut in the piece called the laboratory, and the other in the dome. In moſt of the ready made reverberatory furnaces which are ſold by the potters at Paris, the openings both above and below are too ſmall: Theſe do not allow a ſufficient volume of air to paſs through; hence, as the quantity of charcoal conſumed, or, what is much the ſame thing, the quantity of caloric diſengaged, is nearly in proportion to the quantity of air which paſſes through the furnace, theſe furnaces do not produce a ſufficient effect in a great number of experiments. To remedy this defect, there ought to be two openings GG to the aſh-hole; one of theſe is ſhut up when only a moderate fire is required; and both are kept open when the ſtrongeſt power of the furnace is to be exerted. The opening of the dome SS ought likewiſe to be conſiderably larger than is uſually made.

It is of great importance not to employ retorts of too large ſize in proportion to the furnace, as a ſufficient ſpace ought always to be allowed for the paſſage of the air between the ſides of the furnace and the veſſel. The retort A in the figure is too ſmall for the ſize of the furnace, yet I find it more eaſy to point out the error than to correct it. The intention of the dome is to oblige the flame and heat to ſurround and ſtrike back or reverberate upon every part of the retort, whence the furnace gets the name of reverberatory. Without this circumſtance the retort would only be heated in its bottom, the vapours raiſed from the contained ſubſtance would condenſe in the upper part, and a continual cohabitation would take place without any thing paſſing over into the receiver; but, by means of the dome, the retort is equally heated in every part, and the vapours being forced out, can only condenſe in the neck of the retort, or in the recipient.

To prevent the bottom of the retort from being either heated or coolled too ſuddenly, it is ſometimes placed in a ſmall ſand-bath of baked clay, ſtanding upon the croſs bars of the furnace. Likewiſe, in many operations, the retorts are coated over with lutes, ſome of which are intended to preſerve them from the too ſudden influence of heat or of cold, while others are for ſuſtaining the glaſs, or forming a kind of ſecond retort, which ſupports the glaſs one during operations wherein the ſtrength of the fire might ſoften it. The former is made of brick-clay with a little cow's hair beat up alongſt with it, into a paſte or mortar, and ſpread over the glaſs or ſtone retorts. The latter is made of pure clay and pounded ſtone-ware mixed together, and uſed in the ſame manner. This dries and hardens by the fire, ſo as to form a true ſupplementary retort capable of retaining the materials, if the glaſs retort below ſhould crack or ſoften. But, in experiments which are intended for collecting gaſſes, this lute, being porous, is of no manner of uſe.

In a great many experiments wherein very violent fire is not required, the reverberatory furnace may be uſed as a melting one, by leaving out the piece called the laboratory, and placing the dome immediately upon the fire-place, as repreſented Pl. XIII. Fig. 3. The furnace repreſented in Fig. 4. is very convenient for fuſions; it is compoſed of the fire-place and aſh-hole ABD, without a door, and having a hole E, which receives the muzzle of a pair of bellows ſtrongly luted on, and the dome ABGH, which ought to be rather lower than is repreſented in the figure. This furnace is not capable of producing a very ſtrong heat, but is ſufficient for ordinary operations, and may be readily moved to any part of the laboratory where

where it is wanted. Though theſe particular furnaces are very convenient, every laboratory muſt be provided with a forge furnace, having a good pair of bellows, or, what is more neceſſary, a powerful melting furnace. I ſhall deſcribe the one I uſe, with the principles upon which it is conſtructed.

The air circulates in a furnace in conſequence of being heated in its paſſage through the burning coals; it dilates, and, becoming lighter than the ſurrounding air, is forced to riſe upwards by the preſſure of the lateral columns of air, and is replaced by freſh air from all ſides, eſpecially from below. This circulation of air even takes place when coals are burnt in a common chaffing diſh; but we can readily conceive, that, in a furnace open on all ſides, the maſs of air which paſſes, all other circumſtances being equal, cannot be ſo great as when it is obliged to paſs through a furnace in the ſhape of a hollow tower, like moſt of the chemical furnaces, and conſequently, that the combuſtion muſt be more rapid in a furnace of this latter conſtruction. Suppoſe, for inſtance, the furnace ABCDEF open above, and filled with burning coals, the force with which the air paſſes through the coals will be in proportion to the difference between the ſpecific gravity of two columns equal to AC, the one of cold air without, and the other of heated air within the furnace.

There

There muſt be ſome heated air above the opening AB, and the ſuperior levity of this ought likewiſe to be taken into conſideration; but, as this portion is continually coolled and carried off by the external air, it cannot produce any great effect.

But, if we add to this furnace a large hollow tube GHAB of the ſame diameter, which preſerves the air which has been heated by the burning coals from being coolled and diſperſed by the ſurrounding air, the difference of ſpecific gravity which cauſes the circulation will then be between two columns equal to GC. Hence, if GC be three times the length of AC, the circulation will have treble force. This is upon the ſuppoſition that the air in GHCD is as much heated as what is contained in ABCD, which is not ſtrictly the caſe, becauſe the heat muſt decreaſe between AB and GH; but, as the air in GHAB is much warmer than the external air, it follows, that the addition of the tube muſt increaſe the rapidity of the ſtream of air, that a larger quantity muſt paſs through the coals, and conſequently that a greater degree of combuſtion muſt take place.

We muſt not, however, conclude from theſe principles, that the length of this tube ought to be indefinitely prolonged; for, ſince the heat of the air gradually diminiſhes in paſſing from AB to GH, even from the contact of the ſides of the tube,

tube, if the tube were prolonged to a certain degree, we would at laſt come to a point where the ſpecific gravity of the included air would be equal to the air without; and, in this caſe, as the cool air would no longer tend to riſe upwards, it would become a gravitating maſs, reſiſting the aſcenſion of the air below. Beſides, as this air, which has ſerved for combuſtion, is neceſſarily mixed with carbonic acid gas, which is conſiderably heavier than common air, if the tube were made long enough, the air might at laſt approach ſo near to the temperature of the external air as even to gravitate downwards; hence we muſt conclude, that the length of the tube added to a furnace muſt have ſome limit beyond which it weakens, inſtead of ſtrengthening the force of the fire.

From theſe reflections it follows, that the firſt foot of tube added to a furnace produces more effect than the ſixth, and the ſixth more than the tenth; but we have no data to aſcertain at what height we ought to ſtop. This limit of uſeful addition is ſo much the farther in proportion as the materials of the tube are weaker conductors of heat, becauſe the air will thereby be ſo much leſs coolled; hence baked earth is much to be preferred to plate iron. It would be even of conſequence to make the tube double, and to fill the interval with rammed charcoal, which is one of the worſt conductors of heat known;

known; by this the refrigeration of the air will be retarded, and the rapidity of the ſtream of air conſequently increaſed; and, by this means, the tube may be made ſo much the longer.

As the fire-place is the hotteſt part of a furnace, and the part where the air is moſt dilated in its paſſage, this part ought to be made with a conſiderable widening or belly. This is the more neceſſary, as it is intended to contain the charcoal and crucible, as well as for the paſſage of the air which ſupports, or rather produces the combuſtion; hence we only allow the interſtices between the coals for the paſſage of the air.

From theſe principles my melting furnace is conſtructed, which I believe is at leaſt equal in power to any hitherto made, though I by no means pretend that it poſſeſſes the greateſt poſſible intenſity that can be produced in chemical furnaces. The augmentation of the volume of air produced during its paſſage through a melting furnace not being hitherto aſcertained from experiment, we are ſtill unacquainted with the proportions which ſhould exiſt between the inferior and ſuperior apertures, and the abſolute ſize of which theſe openings ſhould be made is ſtill leſs underſtood; hence data are wanting by which to proceed upon principle, and we can only accompliſh the end in view by repeated trials.

This furnace, which, according to the above ſtated rules, is in form of an eliptical ſpheroid, is repreſented Pl. XIII. Fig. 6. ABCD; it is cut off at the two ends by two plains, which paſs, perpendicular to the axis, through the foci of the elipſe. 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, after the model of Mr Macquer's melting furnace, and ſtands upon an iron tripod. The grate is made of flat bars ſet on edge, and with conſiderable interſtices. To the upper part is added a chimney, or tube, of baked earth, ABFG, about eighteen feet long, and almoſt half the diameter of the furnace. Though this furnace produces a greater heat than any hitherto employed by chemiſts, it is ſtill ſuſceptible of being conſiderably increaſed in power by the means already mentioned, the principal of which is to render the tube as bad a conductor of heat as poſſible, by making it double, and filling the interval with rammed charcoal.

When it is required to know if lead contains any mixture of gold or ſilver, it is heated in a ſtrong fire in capſules of calcined bones, which are called cuppels. The lead is oxydated, becomes vitrified, and ſinks into the ſubſtance of the

the cuppel, while the gold or ſilver, being incapable of oxydation, remain pure. As lead will not oxydate without free acceſs of air, this operation cannot be performed in a crucible placed in the middle of the burning coals of a furnace, becauſe the internal air, being moſtly already reduced by the combuſtion into azotic and carbonic acid gas, is no longer fit for the oxydation of metals. It was therefore neceſſary to contrive a particular apparatus, in which the metal ſhould be at the ſame time expoſed to the influence of violent heat, and defended from contact with air rendered incombuſtible by its paſſage through burning coals. The furnace intended for anſwering this double purpoſe is called the cuppelling or eſſay furnace. It is uſually made of a ſquare form, as repreſented Pl. XIII. Fig. 8. and 10. having an aſh-hole AABB, a fire-place BBCC, a laboratory CCDD, and a dome DDEE. The muffle or ſmall oven of baked earth GH, Fig. 9. being placed in the laboratory of the furnace upon croſs bars of iron, is adjuſted to the opening GG, and luted with clay ſoftened in water. The cuppels are placed in this oven or muffle, and charcoal is conveyed into the furnace through the openings of the dome and fire-place. The external air enters through the openings of the aſh-hole for ſupporting the combuſtion, and eſcapes by the ſuperior opening or chimney at EE; and air is

admitted

admitted through the door of the muffle GG for oxydating the contained metal.

Very little reflection is ſufficient to diſcover the erroneous principles upon which this furnace is conſtructed. When the opening GG is ſhut, the oxydation is produced ſlowly, and with difficulty, for want of air to carry it on; and, when this hole is open, the ſtream of cold air which is then admitted fixes the metal, and obſtructs the proceſs. Theſe inconveniencies may be eaſily remedied, by conſtructing the muffle and furnace in ſuch a manner that a ſtream of freſh external air ſhould always play upon the ſurface of the metal, and this air ſhould be made to paſs through a pipe of clay kept continually red hot by the fire of the furnace. By this means the inſide of the muffle will never be coolled, and proceſſes will be finiſhed in a few minutes, which at preſent require a conſiderable ſpace of time.

Mr Sage remedies theſe inconveniencies in a different manner; he places the cuppel containing lead, alloyed with gold or ſilver, amongſt the charcoal of an ordinary furnace, and covered by a ſmall porcelain muffle; when the whole is ſufficiently heated, he directs the blaſt of a common pair of hand-bellows upon the ſurface of the metal, and completes the cuppellation in this way with great eaſe and exactneſs.

SECT. III.

Of increaſing the Action of Fire, by uſing Oxygen Gas inſtead of Atmoſpheric Air.

By means of large burning glaſſes, ſuch as thoſe of Tchirnauſen and Mr de Trudaine, a degree of heat is obtained ſomewhat greater than has hitherto been produced in chemical furnaces, or even in the ovens of furnaces uſed for baking hard porcelain. But theſe inſtruments are extremely expenſive, and do not even produce heat ſufficient to melt crude platina; ſo that their advantages are by no means ſufficient to compenſate for the difficulty of procuring, and even of uſing them. Concave mirrors produce ſomewhat more effect than burning glaſſes of the ſame diameter, as is proved by the experiments of Meſſrs Macquer and Beaumé with the ſpeculum of the Abbé Bouriot; but, as the direction of the reflected rays is neceſſarily from below upwards, the ſubſtance to be operated upon muſt be placed in the air without any ſupport, which renders moſt chemical experiments impoſſible to be performed with this inſtrument.

For theſe reaſons, I firſt endeavoured to employ oxygen gas for combuſtion, by filling large bladders with it, and making it paſs through a tube capable of being ſhut by a ſtop-cock; and in this way I ſucceeded in cauſing it to ſupport the combuſtion of lighted charcoal. The intenſity of the heat produced, even in my firſt attempt, was ſo great as readily to melt a ſmall quantity of crude platina. To the ſucceſs of this attempt is owing the idea of the gazometer, deſcribed p. 308. *et ſeq.* which I ſubſtituted inſtead of the bladders; and, as we can give the oxygen gas any neceſſary degree of preſſure, we can with this inſtrument keep up a continued ſtream, and give it even a very conſiderable force.

The only apparatus neceſſary for experiments of this kind conſiſts of a ſmall table ABCD, Pl. XII. Fig. 15. with a hole F, through which paſſes a tube of copper or ſilver, ending in a very ſmall opening at G, and capable of being opened or ſhut by the ſtop-cock H. This tube is continued below the table at *lmno*, and is connected with the interior cavity of the gazometer. When we mean to operate, a hole of a few lines deep muſt be made with a chizel in a piece of charcoal, into which the ſubſtance to be treated is laid; the charcoal is ſet on fire by means of a candle and blow-pipe, after which it is expoſed to a rapid ſtream of oxygen gas from the extremity G of the tube FG.

This manner of operating can only be uſed with ſuch bodies as can be placed, without inconvenience, in contact with charcoal, ſuch as metals, ſimple earths, &c. But, for bodies whoſe elements have affinity to charcoal, and which are conſequently decompoſed by that ſubſtance, ſuch as ſulphats, phoſphats, and moſt of the neutral ſalts, metallic glaſſes, enamels, &c. we muſt uſe a lamp, and make the ſtream of oxygen gas paſs through its flame. For this purpoſe, we uſe the elbowed blow-pipe ST, inſtead of the bent one FG, employed with charcoal. The heat produced in this ſecond manner is by no means ſo intenſe as in the former way, and is very difficultly made to melt platina. In this manner of operating with the lamp, the ſubſtances are placed in cuppels of calcined bones, or little cups of porcelain, or even in metallic diſhes. If theſe laſt are ſufficiently large, they do not melt, becauſe, metals being good conductors of heat, the caloric ſpreads rapidly through the whole maſs, ſo that none of its parts are very much heated.

In the Memoirs of the Academy for 1782, p. 476. and for 1783, p. 573. the ſeries of experiments I have made with this apparatus may be ſeen at large. The following are ſome of the principal reſults.

1. Rock

1. Rock criſtal, or pure ſilicious earth, is infuſible, but becomes capable of being ſoftened or fuſed when mixed with other ſubſtances.

2. Lime, magneſia, and barytes, are infuſible, either when alone, or when combined together; but, eſpecially lime, they aſſiſt the fuſion of every other body.

3. Argill, or pure baſe of alum, is completely fuſible *per ſe* into a very hard opake vitreous ſubſtance, which ſcratches glaſs like the precious ſtones.

4. All the compound earths and ſtones are readily fuſed into a browniſh glaſs.

5. All the ſaline ſubſtances, even fixed alkali, are volatilized in a few ſeconds.

6. Gold, ſilver, and probably platina, are ſlowly volatilized without any particular phenomenon.

7. All other metallic ſubſtances, except mercury, become oxydated, though placed upon charcoal, and burn with different coloured flames, and at laſt diſſipate altogether.

8. The metallic oxyds likewiſe all burn with flames. This ſeems to form a diſtinctive character for theſe ſubſtances, and even leads me to believe, as was ſuſpected by Bergman, that barytes is a metallic oxyd, though we have not hitherto been able to obtain the metal in its pure or reguline ſtate.

9. Some of the precious ſtones, as rubies, are capable of being ſoftened and ſoldered together, without injuring their colour, or even diminiſhing their weights. The hyacinth, tho' almoſt equally fixed with the ruby, loſes its colour very readily. The Saxon and Braſilian topaz, and the Braſilian ruby, loſe their colour very quickly, and loſe about a fifth of their weight, leaving a white earth, reſembling white quartz, or unglazed china. The emerald, chryſolite, and garnet, are almoſt inſtantly melted into an opake and coloured glaſs.

10. The diamond preſents a property peculiar to itſelf; it burns in the ſame manner with combuſtible bodies, and is entirely diſſipated.

There is yet another manner of employing oxygen gas for conſiderably increaſing the force of fire, by uſing it to blow a furnace. Mr Achard firſt conceived this idea; but the proceſs he employed, by which he thought to dephlogiſticate, as it is called, atmoſpheric air, or to deprive it of azotic gas, is abſolutely unſatiſfactory. I propoſe to conſtruct a very ſimple furnace, for this purpoſe, of very refractory earth, ſimilar to the one repreſented Pl. XIII. Fig. 4. but ſmaller in all its dimenſions. It is to have two openings, as at E, through one of which the nozle of a pair of bellows is to paſs, by which the heat is to be raiſed as high as poſſible with common air; after which, the ſtream of common air from the bellows being ſuddenly ſtopt, oxygen gas is to be admitted by a tube, at the other opening, communicating with a gazometer having the preſſure of four or five inches of water. I can in this manner unite the oxygen gas from ſeveral gazometers, ſo as to make eight or nine cubical feet of gas paſs through the furnace; and in this way I expect to produce a heat greatly more intenſe than any hitherto known. The upper orifice of the furnace muſt be carefully made of conſiderable dimenſions, that the caloric produced may have free iſſue, leſt the too ſudden expanſion of that highly elaſtic fluid ſhould produce a dangerous exploſion.

FINIS.

[illegible]

[illegible]

APPENDIX.

No. I.

TABLE *for Converting Lines, or Twelfth Parts of an Inch, and Fractions of Lines, into Decimal Fractions of the Inch.*

Twelfth Parts of a Line.	Decimal Fractions.	Lines.	Decimal Fractions.
1	0.00694	1	0.08333
2	0.01389	2	0.16667
3	0.02083	3	0.25000
4	0.02778	4	0.33333
5	0.03472	5	0.41667
6	0.04167	6	0.50000
7	0.04861	7	0.58333
8	0.05556	8	0.66667
9	0.06250	9	0.75000
10	0.06944	10	0.83333
11	0.07639	11	0.91667
12	0.08333	12	1.00000

No. II.

Table *for Converting the Obſerved Heighths of Water in the Jars of the Pneumato-Chemical Apparatus, expreſſed in Inches and Decimals, into Correſponding Heighths of Mercury.*

Water.	Mercury.	Water.	Mercury.
.1	.00737	4.	.29480
.2	.01474	5.	.36851
.3	.02201	6.	.44221
.4	.02948	7.	.51591
.5	.03685	8.	.58961
.6	.04422	9.	.66332
.7	.05159	10.	.73702
.8	.05896	11.	.81072
.9	.06633	12.	.88442
1.	.07370	13.	.96812
2.	.14740	14.	1.04182
3.	.22010	15.	1.11525

No.

No. III.

TABLE *for Converting the Ounce Meaſures uſed by Dr Prieſtly into French and Engliſh Cubical Inches.*

Ounce meaſures.	French cubical inches.	Engliſh cubical inches.
1	1.567	1.898
2	3.134	3.796
3	4.701	5.694
4	6.268	7.592
5	7.835	9.490
6	9.402	11.388
7	10.969	13.286
8	12.536	15.184
9	14.103	17.082
10	15.670	18.980
20	31.340	37.960
30	47.010	56.940
40	62.680	75.920
50	78.350	94.900
60	94.020	113.880
70	109.690	132.860
80	125.360	151.840
90	141.030	170.820
100	156.700	189.800
1000	1567.000	1898.000

No. IV. ADDITIONAL.

TABLE *for Reducing the Degrees of Reaumeur's Thermometer into its correſponding Degrees of Fahrenheit's Scale.*

R. F.	R. F.	R. F.	R. F.
0=32	21= 79.25	41=124.25	61=169.25
1=34.25	22= 81.5	42=126.5	62=171.5
2=36.5	23= 83.75	43=128.75	63=173.75
3=38.75	24= 86	44=131	64=176.
4=41	25= 88.25	45=133.25	65=178.25
5=43.25	26= 90.5	46=135.5	66=180.5
6=45.5	27= 92.75	47=137.75	67=182.75
7=47.75	28= 95	48=140	68=185
8=50	29= 97.25	49=142.25	69=187.25
9=52.25	30= 99.5	50=144.5	70=189.5
10=54.5	31=101.75	51=146.75	71=191.75
11=56.75	32=104	52=149	72=194.
12=59	33=106.25	53=151.25	73=196 25
13=61.25	34=108.5	54=153.5	74=198.5
14=63.5	35=110.75	55=155.75	75=200.75
15=65.75	36=113	56=158	76=203
16=68	37=115.25	57=160.25	77=205.25
17=70.25	38=117.5	58=162.5	78=207.5
18=72.5	39=119.75	59=164.75	79=209.75
19=74.75	40=122	60=167	80=212
20=77			

Note—Any degree, either higher or lower, than what is contained in the above Table, may be at any time converted, by remembering that one degree of Reaumeur's ſcale is equal to 2.25° of Fahrenheit; or it may be done without the Table by the following formula, $\frac{R\times 9}{4}+32=F$; that is, multiply the degree of Reaumeur by 9, divide the product by 4, to the quotient add 32, and the ſum is the degree of Fahrenheit. —E.

No. V. Additional.

Rules *for converting French Weights and Meaſures into correſpondent Engliſh Denominations* *.

§ 1. *Weights.*

The Paris pound, poids de mark of Charlemagne, contains 9216 Paris grains; it is divided into 16 ounces, each ounce into 8 gros, and each gros into 72 grains. It is equal to 7561 Engliſh Troy grains.

The Engliſh Troy pound of 12 ounces contains 5760 Engliſh Troy grains, and is equal to 7021 Paris grains.

The Engliſh averdupois pound of 16 ounces contains 7000 Engliſh Troy grains, and is equal to 8538 Paris grains.

To reduce Paris *grs.* to Engliſh Troy *grs.* divide by . . .	1.2189
To reduce Engliſh Troy *grs.* to Paris *grs.* multiply by . .	

To reduce Paris ounces to Engliſh Troy, divide by . . .	1.015734
To reduce Engliſh Troy ounces to Paris, multiply by . .	

Or

---

* For the materials of this Article the Tranſlator is indebted to Profeſſor Robertſon.

Or the converſion may be made by means of the following Tables.

I. *To reduce French to Engliſh Troy Weight.*

The Paris pound = 7561
The ounce = 472.5625
The gros = 59.0703
The grain = .8194
Engliſh. Troy. Grains.

II. *To Reduce Engliſh Troy to Paris Weight.*

The Engliſh Troy pound of 12 ounces =7021.
The Troy ounce = 585.0830
The dram of 60 grs. = 73.1353
The penny weight, or denier, of 24 grs. = 29.2540
The ſcruple, of 20 grs. = 24.3784
Paris grains.

III. *To Reduce Engliſh Averdupois to Paris Weight.*

The averdupois pound of 16 ounces, or 7000 Troy grains. =8538.
The ounce - = 533.6250
Paris grains.

§ 2.

§ 2. *Long and Cubical Meaſures.*

To reduce Paris feet or inches into Engliſh, multiply by - Engliſh feet or inches into Paris, divide by - - -	1.065977
To reduce Paris cubic feet or inches to Engliſh, multiply by - Engliſh cubic feet or inches to Paris, divide by - - -	1.211278

Or by means of the following tables:

IV. *To Reduce Paris Long Meaſure to Engliſh.*

The Paris royal foot of 12 inches - -	=	12.7977	Engliſh inches.
The inch - -	=	1.0659	
The line, or $\frac{1}{12}$ of an inch	=	.0888	
The $\frac{1}{12}$ of a line -	=	.0074	

V. *To Reduce Engliſh Long Meaſure to French.*

The Engliſh foot	=	11.2596	Paris inches.
The inch -	=	.9383	
The $\frac{1}{8}$ of an inch	=	.1173	
The $\frac{1}{10}$ -	=	.0938	
The line, or $\frac{1}{12}$	=	.0782	

VI.

VI. *To Reduce French Cube Meaſure to Engliſh.*

The Paris cube foot	= 1.211278	Engliſh cubical feet, or	2093.088384	inches.
The cubic inch	= .000700		1.211278	

VII. *To Reduce Engliſh Cube Meaſure to French.*

The Engliſh cube foot, or 1728 cubical inches	= 1427.4864	French cubical inches.
The cubical inch	= .8260	
The cube tenth	= .0008	

§ 3. *Meaſure of Capacity.*

The Paris pint contains 58.145 * Engliſh cubical inches, and the Engliſh wine pint contains 28.85 cubical inches; or, the Paris pint contains 2.01508

---

* It is ſaid, *Belidor Archit. Hydrog.* to contain 31 *oz.* 64 *grs.* of water, which makes it 58.075 Engliſh inches; but, as there is conſiderable uncertainty in the determinations of the weight of the French cubical meaſure of water, owing to the uncertainty of the ſtandards made uſe of, it is better to abide by Mr Everard's meaſure, which was with the Exchequer ſtandards, and by the proportions of the Engliſh and French foot, as eſtabliſhed by the French Academy and Royal Society.

2.01508 Engliſh pints, and the Engliſh pint contains .49617 Paris pints; hence,

To reduce the Paris pint to the Engliſh, multiply by - -	2.01508.
To reduce the Engliſh pint to the Paris, divide by - -	

No. VI.

TABLE *of the Weights of the different Gaſſes, at* 28 *French inches, or* 29.84 *Engliſh inches barometrical preſſure, and at* 10° (54.5°) *of temperature, expreſſed in Engliſh meaſure and Engliſh Troy weight.*

Names of the Gaſſes.	Weight of a cubical inch.	Weight of a cubical foot.		
*	*qrs.*	*oz.*	*dr.*	*qrs.*
Atmoſpheric air	.32112	1	1	15
Azotic gas	.30064	1	0	39.5
Oxygen gas	.34211	1	1	51
Hydrogen gas	.02394	0	0	41.26
Carbonic acid gas	.44108	1	4	41
* *				
Nitrous gas	.37000	1	2	39
Ammoniacal gas	.18515	0	5	19.73
Sulphurous acid gas	.71580	2	4	38

---

* Theſe five were aſcertained by Mr Lavoiſier himſelf.—E.

** The laſt three are inſerted by Mr Lavoiſier upon the authority of Mr Kirwan.—E.

No. VII.

TABLES *of the Specific Gravities of different bodies.*

§ 1. *Metallic Subſtances.*

GOLD.

Pure gold of 24 carats melted but not hammered	19.2581
The ſame hammered	19.3617
Gold of the Pariſian ſtandard, 22 carats fine, not hammered *	17.4863
The ſame hammered	17.5894
Gold of the ſtandard of French coin, $21\frac{22}{32}$ carats fine, not hammered	17.4022
The ſame coined	17.6474
Gold of the French trinket ſtandard, 20 carats fine, not hammered	15.7090
The ſame hammered	15.7746

SILVER.

Pure or virgin ſilver, 24 deniers, not hammered	10.4743
The ſame hammered	10.5107
Silver of the Paris ſtandard, 11 deniers 10 grains fine, not hammered †	10.1752
The ſame hammered	10.3765

Silver,

---

* The ſame with Sterling.

† This is 10 *grs.* finer than Sterling.

Silver, ſtandard of French coin, 10 deniers 21 grains fine, not hammered	10.0476
The ſame coined . .	10.4077

PLATINA.

Crude platina in grains . .	15.6017
The ſame, after being treated with muriatic acid . . .	16.7521
Purified platina, not hammered .	19.5000
The ſame hammered .	20.3366
The ſame drawn into wire .	21.0417
The ſame paſſed through rollers .	22.0690

COPPER AND BRASS.

Copper, not hammered . .	7.7880
The ſame wire drawn . .	8.8785
Braſs, not hammered . .	8.3958
The ſame wire drawn . .	8.5441

IRON AND STEEL.

Caſt iron . . .	7.2070
Bar iron, either ſcrewed or not .	7.7880
Steel neither tempered nor ſcrewed	7.8331
Steel ſcrewed but not tempered .	7.8404
Steel tempered and ſcrewed .	7.8180
Steel tempered and not ſcrewed .	7.8163

TIN.

Pure tin from Cornwall melted and not ſcrewed	7.2914
The ſame ſcrewed	7.2994
Malacca tin, not ſcrewed	7.2963
The ſame ſcrewed	7.3065
Molten lead	11.3523
Molten zinc	7.1908
Molten biſmuth	9.8227
Molten cobalt	7.8119
Molten arſenic	5.7633
Molten nickel	7.8070
Molten antimony	6.7021
Crude antimony	4.0643
Glaſs of antimony	4.9464
Molybdena	4.7385
Tungſtein	6.0665
Mercury	13.5681

§ 2. *Precious Stones.*

White Oriental diamond	3.5212
Roſe-coloured Oriental ditto	3.5310
Oriental ruby	4.2833
Spinell ditto	3.7600
Ballas ditto	3.6458
Braſillian ditto	3.5311
Oriental topas	4.0106

Ditto

Ditto Piſtachio ditto	4.0615
Braſillian ditto	3.5365
Saxon topas	3.5640
Ditto white ditto	3.5535
Oriental ſaphir	3.9941
Ditto white ditto	3.9911
Saphir of Puy	4.0769
Ditto of Braſil	3.1307
Giraſol	4.0000
Ceylon jargon	4.4161
Hyacinth	3.6873
Vermillion	4.2299
Bohemian garnet	4.1888
Dodecahedral ditto	4.0627
Syrian ditto	4.0000
Volcanic ditto, with 24 ſides	2.4684
Peruvian emerald	2.7755
Cryſolite of the jewellers	2.7821
Ditto of Braſil	2.6923
Beryl, or Oriental aqua marine	3.5489
Occidental aqua marine	2.7227

§ 3. *Silicious Stones.*

Pure rock criſtal of Madagaſcar	2.6530
Ditto of Braſil	2.6526
Ditto of Europe, or gelatinous	2.6548
Criſtallized quartz	2.6546
Amorphous ditto	2.6471

Oriental

Oriental agate	2.5901
Agate onyx	2.6375
Tranſparent calcedony	2.6640
Carnelian	2.6137
Sardonyx	2.6025
Praſe	2.5805
Onyx pebble	2.6644
Pebble of Rennes	2.6538
White jade	2.9502
Green jade	2.9660
Red jaſper	2.6612
Brown ditto	2.6911
Yellow ditto	2.7101
Violet ditto	2.7111
Gray ditto	2.7640
Jaſponyx	2.8160
Black priſmatic hexahedral ſchorl	3.3852
Black ſpary ditto	3.3852
Black amorphous ſchorl, called antique baſaltes	2.9225
Paving ſtone	2.4158
Grind ſtone	2.1429
Cutler's ſtone	2.1113
Fountainbleau ſtone	2.5616
Scyth ſtone of Auvergne	2.5638
Ditto of Lorrain	2.5298
Mill ſtone	2.4835
White flint	2.5941
Blackiſh ditto	2.5817

§ 4. *Various Stones, &c.*

Opake green Italian ſerpentine, or gabro of the Florentines	2.4295
Coarſe Briancon chalk	2.7274
Spaniſh chalk	2.7902
Foliated lapis ollaris of Dauphiny	2.7687
Ditto ditto from Sweden	2.8531
Muſcovy talc	2.7917
Black mica	2.9004
Common ſchiſtus or ſlate	2.6718
New ſlate	2.8535
White raſor hone	2.8763
Black and white hone	3.1311
Rhombic or Iceland criſtal	2.7151
Pyramidal calcareous ſpar	2.7141
Oriental or white antique alabaſter	2.7302
Green Campan marble	2.7417
Red Campan marble	2.7242
White Carara marble	2.7168
White Parian marble	2.8376
Various kinds of calcareous ſtones uſed in France for building.	from 1.3864 to 2.3902
Heavy ſpar	4.4300
White fluor	3.1555
Red ditto	3.1911
Green ditto	3.1817
Blue ditto	3.1688
Violet ditto	3.1757

Red ſcintilant zeolite from Edelfors	2.4868
White ſcintilant zeolite	2.0739
Criſtallized zeolite	2.0833
Black pitch ſtone	2.0499
Yellow pitch ſtone	2.0860
Red ditto	2.6695
Blackiſh ditto	2.3191
Red porphyry	2.7651
Ditto of Dauphiny	2.7033
Green ſerpentine	2.8960
Black ditto of Dauphiny, called variolite	2.9339
Green ditto from Dauphiny	2.9883
Ophites	2.9722
Granitello	3.0626
Red Egyptian granite	2.6541
Beautiful red granite	2.7609
Granite of Girardmas	2.7163
Pumice ſtone	.9145
Lapis obſidianus	2.3480
Pierre de Volvic	2.3205
Touch ſtone	2.4153
Baſaltes from Giants Cauſeway	2.8642
Ditto priſmatic from Auvergne	2.4153
Glaſs gall	2.8548
Bottle glaſs	2.7325
Green glaſs	2.6423
White glaſs	2.8922
St Gobin criſtal	2.4882
Flint glaſs	3.3293
Borax glaſs	2.6070

Seves porcelain	2.1457
Limoges ditto	2.3410
China ditto	2.3847
Native ſulphur	2.0332
Melted ſulphur	1.9907
Hard peat	1.3290
Ambergreaſe	.9263
Yellow tranſparent amber.	1.0780

§ 5. *Liquids.*

Diſtilled water	1.0000
Rain water	1.0000
Filtered water of the Seine	1.00015
Arcueil water	1.00046
Avray water	1.00043
Sea water	1.0263
Water of the Dead Sea	1.2403
Burgundy wine	.9915
Bourdeaux ditto	.9939
Malmſey Madeira	1.0382
Red beer	1.0338
White ditto	1.0231
Cyder	1.0181
Highly rectified alkohol	.8293
Common ſpirits of wine	.8371

Alkohol

Alkohol	15 pts.	water 1 part.	.8527
	14	2	.8674
	13	3	.8815
	12	4	.8947
	11	5	.9075
	10	6	.9199
	9	7	.9317
	8	8	.9427
	7	9	.9519
	6	10	.9594
	5	11	.9674
	4	12	.6733
	3	13	.9791
	2	14	.9852
	1	15	.9919

Sulphuric ether . . .	.7394
Nitric ether	.9088
Muriatic ether . . .	.7298
Acetic ether . . .	.8664
Sulphuric acid	1.8409
Nitric ditto . . .	1.2715
Muriatic ditto	1.1940
Red acetous ditto . . .	1.0251
White acetous ditto . . .	1.0135
Diſtilled ditto ditto . .	1.0095
Acetic ditto	1.0626
Formic ditto	.9942
Solution of cauſtic ammoniac, or volatil alkali fluor . .	.8970

Eſſential

Eſſential or volatile oil of turpentine	.8697
Liquid turpentine	.9910
Volatile oil of lavender	.8938
Volatile oil of cloves	1.0363
Volatile oil of cinnamon	1.0439
Oil of olives	.9153
Oil of ſweet almonds	.9170
Lintſeed oil	.9403
Oil of poppy ſeed	.9288
Oil of beech maſt	.9176
Whale oil	.9233
Womans milk	1.0203
Mares milk	1.0346
Aſs milk	1.0355
Goats milk	1.0341
Ewe milk	1.0409
Cows milk	1.0324
Cow whey	1.0193
Human urine	1.0106

§ 6. *Reſins and Gums*

Common yellow or white roſin	1.0727
Arcanſon	1.0857
Galipot *	1.0819
Baras *	1.0441

Sandarac

---

* Reſinous juices extracted in France from the Pine. *Vide Bomare's Dict.*

Sandarac	1.0920
Maſtic	1.0742
Storax	1.1098
Opake copal	1.1398
Tranſparent ditto	1.0452
Madagaſcar ditto	1.0600
Chineſe ditto	1.0628
Elemi	1.0182
Oriental anime	1.0284
Occidental ditto	1.0426
Labdanum	1.1862
Ditto *in tortis*	2.4933
Reſin of guaiac	1.2289
Ditto of jallap	1.2185
Dragons blood	1.2045
Gum lac	1.1390
Tacamahaca	1.0463
Benzoin	1.0924
Alouchi *	1.0604
Caragna †	1.1244
Elaſtic gum	.9335
Camphor	.9887
Gum ammoniac	1.2071
Sagapenum	1.2008

---

* Odoriferous gum from the tree which produces the Cortex Winteranus. *Bomare.*

† Reſin of the tree called in Mexico Caragna, or Tree of Madneſs. *Ibid.*

Ivy gum *	1.2948
Gamboge	1.2216
Euphorbium	1.1244
Olibanum	1.1732
Myrrh	1.3600
Bdellium	1.3717
Aleppo Scamony	1.2354
Smyrna ditto	1.2743
Galbanum	1.2120
Aſſafoetida	1.3275
Sarcocolla	1.2684
Opoponax	1.6226
Cherry tree gum	1.4817
Gum Arabic	1.4523
Tragacanth	1.3161
Baſora gum	1.4346
Acajou gum †	1.4456
Monbain gum ‡	1.4206
Inſpiſſated juice of liquorice	1.7228
———————— Acacia	1.5153
———————— Areca	1.4573
Terra Japonica	1.3980
Hepatic aloes	1.3586
Socotrine aloes	1.3795
Inſpiſſated juice of St John's wort	1.5263

Opium

---

* Extracted in Perſia and the warm countries from Hedera terreſtris.—*Bomare.*

† From a Braſilian tree of this name.—*Ibid.*

‡ From a tree of this name.—*Ibid.*

Opium	1.3366
Indigo	.7690
Arnotto	.5956
Yellow wax	.9648
White ditto	.9686
Ouarouchi ditto *	.8970
Cacao butter	.8916
Spermaceti	.9433
Beef fat	.9232
Veal fat	.9342
Mutton fat	.9235
Tallow	.9419
Hoggs fat	.9368
Lard	.9478
Butter	.9423

§ 7. *Woods.*

Heart of oak 60 years old	1.1700
Cork	.2400
Elm trunk	.6710
Aſh ditto	.8450
Beech	.8520
Alder	.8000
Maple	.7550
Walnut	.6710
Willow	.5850
Linden	.6040

---

* The produce of the Tallow Tree of Guayana. *Vide Bomare's Dict.*

Male fir	.5500
Female ditto	.4980
Poplar	.3830
White Spaniſh ditto	.5294
Apple tree	.7930
Pear tree	.6610
Quince tree	.7050
Medlar	.9440
Plumb tree	.7850
Olive wood	.9270
Cherry tree	.7150
Filbert tree	.6000
French box	.9120
Dutch ditto	1.3280
Dutch yew	.7880
Spaniſh ditto	.8070
Spaniſh cypreſs	.6440
American cedar	.5608
Pomgranate tree	1.3540
Spaniſh mulberry tree	.8970
Lignum vitae	1.3330
Orange tree	.7050

No.

Note—The numbers in the above Table, if the Decimal point be carried three figures farther to the right hand, nearly expreſs the abſolute weight of an Engliſh cube foot of each ſubſtance in averdupois ounces. See No. VIII. of the Appendix.—E.

No. VIII. Additional.

Rules *for Calculating the Abſolute Gravity in Engliſh Troy Weight of a Cubic Foot and Inch, Engliſh Meaſure, of any Subſtance whoſe Specific Gravity is known* *.

In 1696, Mr Everard, balance-maker to the Exchequer, weighed before the Commiſſioners of the Houſe of Commons 2145.6 cubical inches, by the Exchequer ſtandard foot, of diſtilled water, at the temperature of 55° of Fahrenheit, and found it to weigh 1131 oz. 14 dts. Troy, of the Exchequer ſtandard. The beam turned with 6 grs. when loaded with 30 pounds in each ſcale. Hence, ſuppoſing the pound averdupois to weigh 7000 grs. Troy, a cubic foot of water weighs $62\frac{1}{2}$ pounds averdupois, or 1000 ounces averdupois, wanting 106 grains Troy. And hence, if the ſpecific gravity of water be called 1000, the proportional ſpecific gravities of all other bodies will nearly expreſs the number of averdupois ounces in a cubic foot. Or more accurately, ſuppoſing the ſpecific gravity of water expreſſed by 1. and of all other bodies in proportional numbers, as the cubic

---

* The whole of this and the following article was communicated to the Tranſlator by Profeſſor Robinſon. —E.

cubic foot of water weighs, at the above temperature, exactly 437489.4 grains Troy, and the cubic inch of water 253.175 grains, the abſolute weight of a cubical foot or inch of any body in Troy grains may be found by multiplying their ſpecific gravity by either of the above numbers reſpectively.

By Everard's experiment, and the proportions of the Engliſh and French foot, as eſtabliſhed by the Royal Society and French Academy of Sciences, the following numbers are aſcertained.

Paris grains in a Paris cube foot of water - - - = 645511
Engliſh grains in a Paris cube foot of water - - - = 529922
Paris grains in an Engliſh cube foot of water - - - = 533247
Engliſh grains in an Engliſh cube foot of water - = 437489.4
Engliſh grains in an Engliſh cube inch of water - - = 253.175

By an experiment of Picard with the meaſure and weight of the Chatelet, the Paris cube foot of water contains of Paris grains = 641326
By one of Du Hamel, made with great care - - - = 641376
By Homberg - - - = 641666

Theſe

Theſe ſhow ſome uncertainty in meaſures or in weights; but the above computation from Everard's experiment may be relied on, becauſe the compariſon of the foot of England with that of France was made by the joint labours of the Royal Society of London and the French Academy of Sciences: It agrees likewiſe very nearly with the weight aſſigned by Mr Lavoiſier, 70 Paris pounds to the cubical foot of water.

No. IX.

Tables *for Converting Ounces, Drams, and Grains, Troy, into Decimals of the Troy Pound of* 12 *Ounces, and for Converting Decimals of the Pound Troy into Ounces, &c.*

I. *For Grains.*

Grains	= Pound.	Grains	= Pound.
1	.0001736	100	.0173611
2	.0003472	200	.0374222
3	.0005208	300	.0520833
4	.0006944	400	.0694444
5	.0008681	500	.0868055
6	.0010417	600	.1041666
7	.0012153	700	.1215277
8	.0013889	800	.1388888
9	.0015625	900	.1562499
10	.0017361	1000	.1736110
20	.0034722	2000	.3472220
30	,0052083	3000	.5208330
40	,0069444	4000	.6944440
50	.0086806	5000	.8680550
60	.0104167	6000	1.0418660
70	.0121528	7000	1.2152770
80	.0138889	8000	1.3888880
90	.0156250	9000	1.5624990

II.

II. *For Drams.*

Drams =	Pound.
1	.0104167
2	.0208333
3	.0312500
4	.0416667
5	.0520833
6	.0625000
7	.0729167
8	.0833333

III. *For Ounces.*

Ounces =	Pounds.
1	.0833333
2	.1666667
3	.2500000
4	.3333333
5	.4166667
6	.5000000
7	.5833333
8	.6666667
9	.7500000
10	.8333333
11	.9166667
12	1.0000000

IV. *Decimals of the Pound into Ounces, &c.*

Tenth parts.				*Thouſandths.*	
lib. =	*oz.*	*dr.*	*gr.*	*lib.* =	*grs.*
0.1	1	1	36	0.006	34.56
0.2	2	3	12	0.007	40.32
0.3	3	4	48	0.008	46.08
0.4	4	6	24	0.009	51.84
0.5	6	0	0	*Ten thouſandth parts.*	
0.6	7	1	36	0.0001	0.576
0.7	8	3	12	0.0002	1.152
0.8	9	4	48	0.0003	1.728
0.9	10	6	24	0.0004	2.304
Hundredth parts.				0.0005	2.880
0.01	0	0	57.6	0.0006	3.456
0.02	0	1	55.2	0.0007	4.032
0.03	0	2	52.8	0.0008	4.608
0.04	0	3	50.4	0.0009	5.184
0.05	0	4	48.0	*Hundred thouſandth parts.*	
0.06	0	5	45.6		
0.07	0	6	43.2	0.00001	0.052
0.08	0	7	40.8	0.00002	0.115
0.09	0	3	38.4	0.00003	0.173
Thouſandths.				0.00004	0.230
0.001	0	0	5.76	0.00005	0.288
0.002	0	0	11.52	0.00006	0.346
0.003	0	0	17.28	0.00007	0.403
0.004	0	0	23.04	0.00008	0.461
0.005	0	0	28.80	0.00009	0.518

No. X.

TABLE *of the Engliſh Cubical Inches and Decimals correſponding to a determinate Troy Weight of Diſtilled Water at the Temperature of* 55°, *calculated from Everard's experiment.*

For Grains.

Grs.		Cubical inches.
1	=	.0039
2		.0078
3		.0118
4		.0157
5		.0197
6		.0236
7		.0275
8		.0315
9		.0354
10		.0394
20		.0788
30		.1182
40		.1577
50		.1971

For Drams.

Drams.		Cubical inches.
1	=	.2365
2		.4731
3		.7094
4		.9463
5		1.1829
6		1.4195
7		1.6561

For Ounces.

Oz.		Cubical inches.
1	=	1.8927
2		3.7855
3		5.6782
4		7.5710
5		9.4631
6		11.3565
7		13.2493
8		15.1420
9		17.0748
10		18.9276
11		20.8204

For Pounds.

Libs.		Cubical inches.
1	=	22.7131
2		45.4263
3		68.1394
4		90.8525
5		113.5657
6		136.2788
7		158.9919
8		181.7051
9		204.4183
10		227.1314
50		1135.6574
100		2271.3148
1000		22713.1488

THE END.

PLATE I.

Fig. 5.

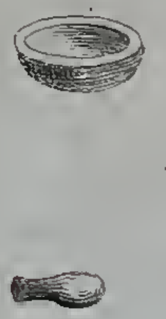


Fig. 4.

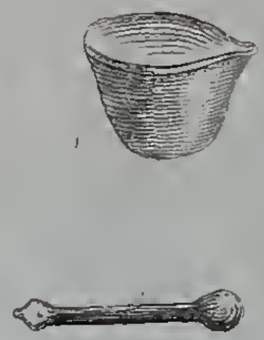


Fig. 3.

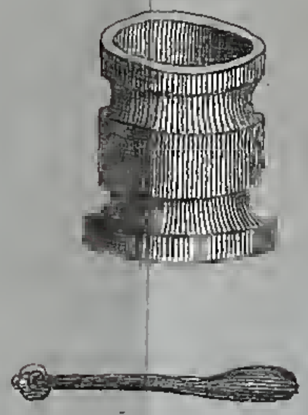


Fig. 2.

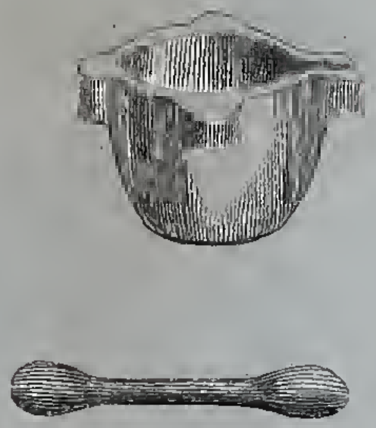


Fig. 1.

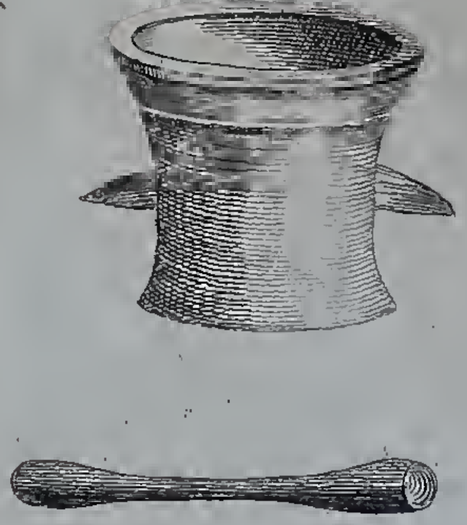


Fig. 16.

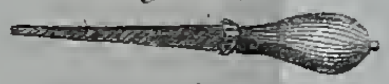


Fig. 13.

Fig. 12.

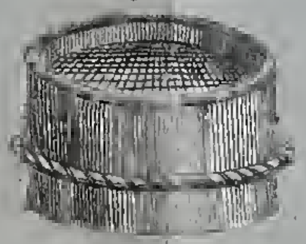


Fig. 9.

Fig. 6.

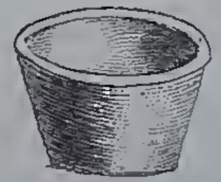


Fig. 7.

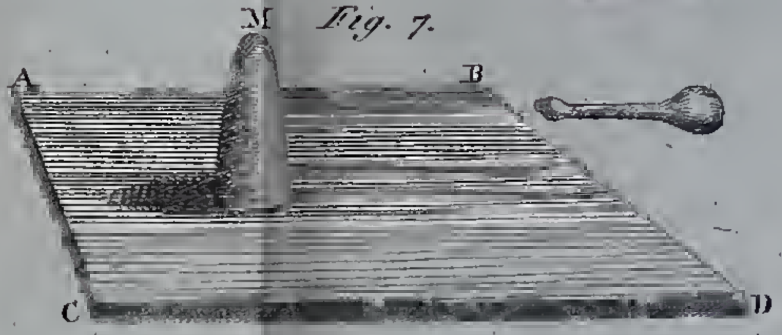


Fig. 15.

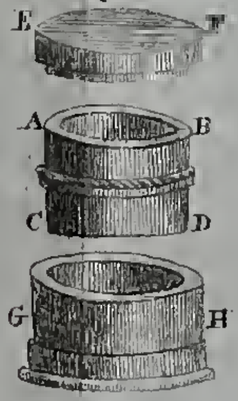


Fig. 14.

Fig. 8.

Fig. 11.

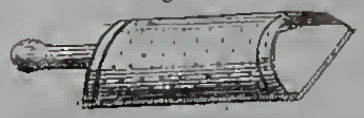
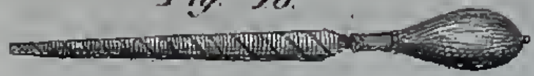


Fig. 10.



D. Lizars Sculpt

Fig. 1.

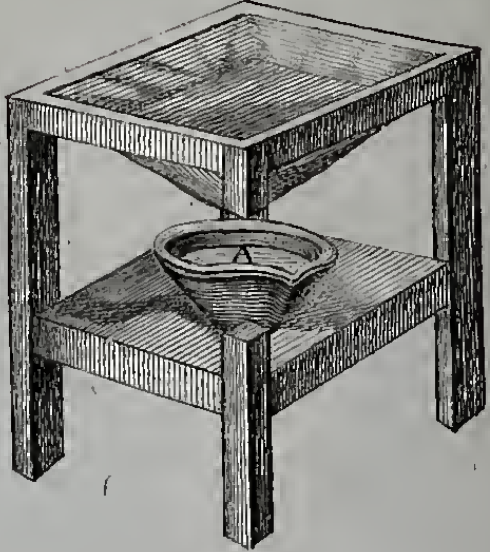


Fig. 2.

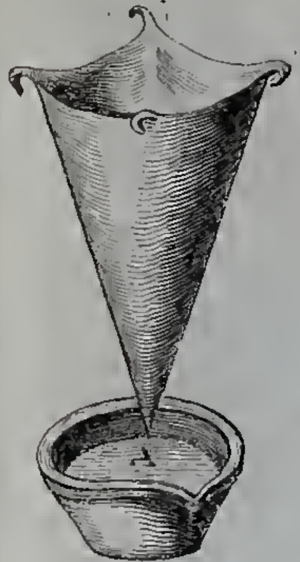


Fig. 5.

Fig. 7.

Fig. 6.

Fig. 8.

Fig. 3.

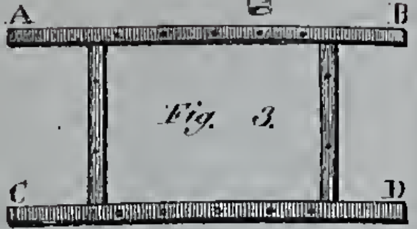


Fig. 10.

Fig. 9.

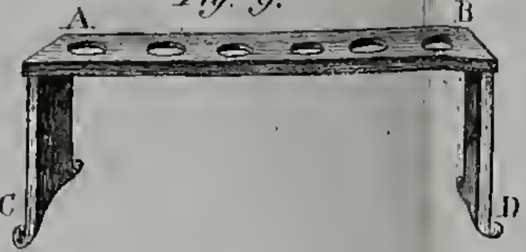


Fig. 4.

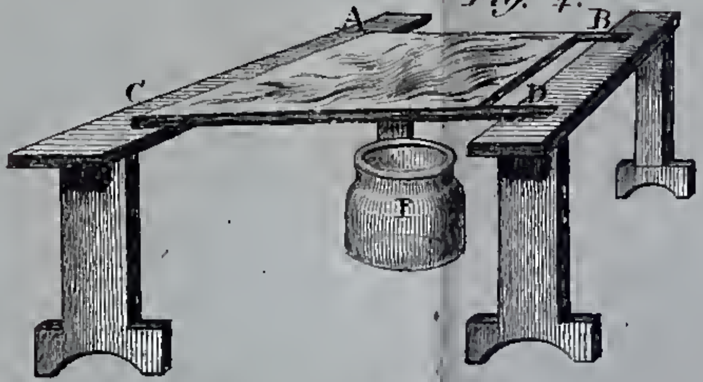


Fig. 14.

Fig. 11.

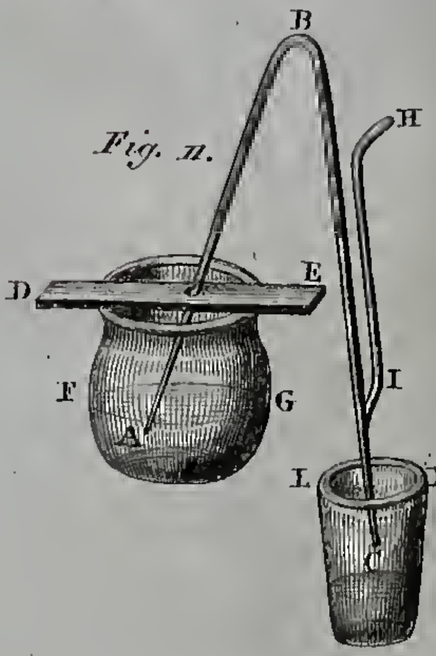


Fig. 12.

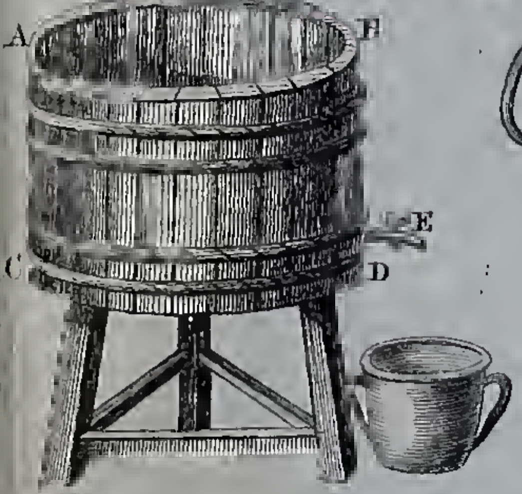
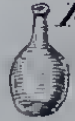


Fig. 13.

Fig. 15.

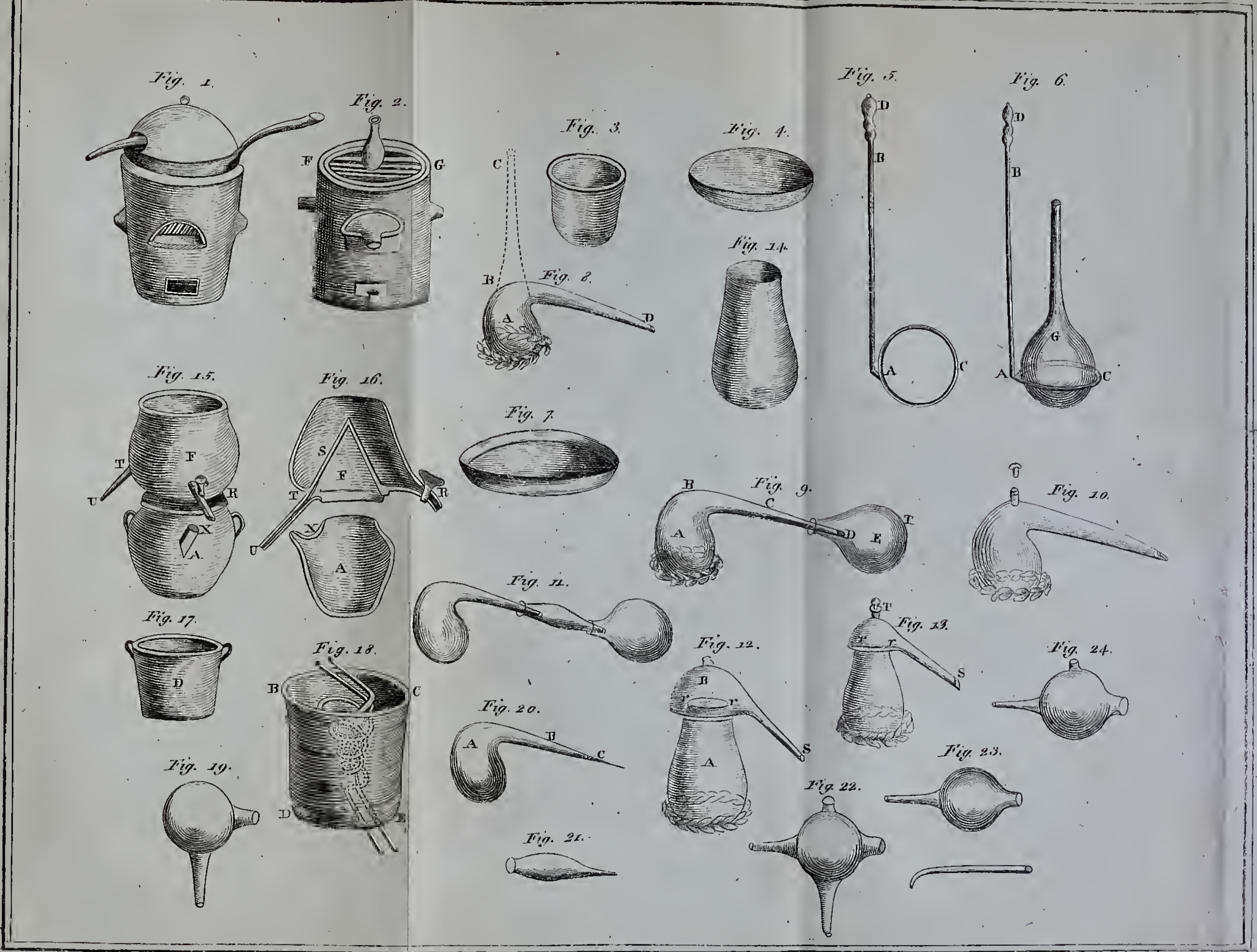
Fig. 16.

Fig. 17.



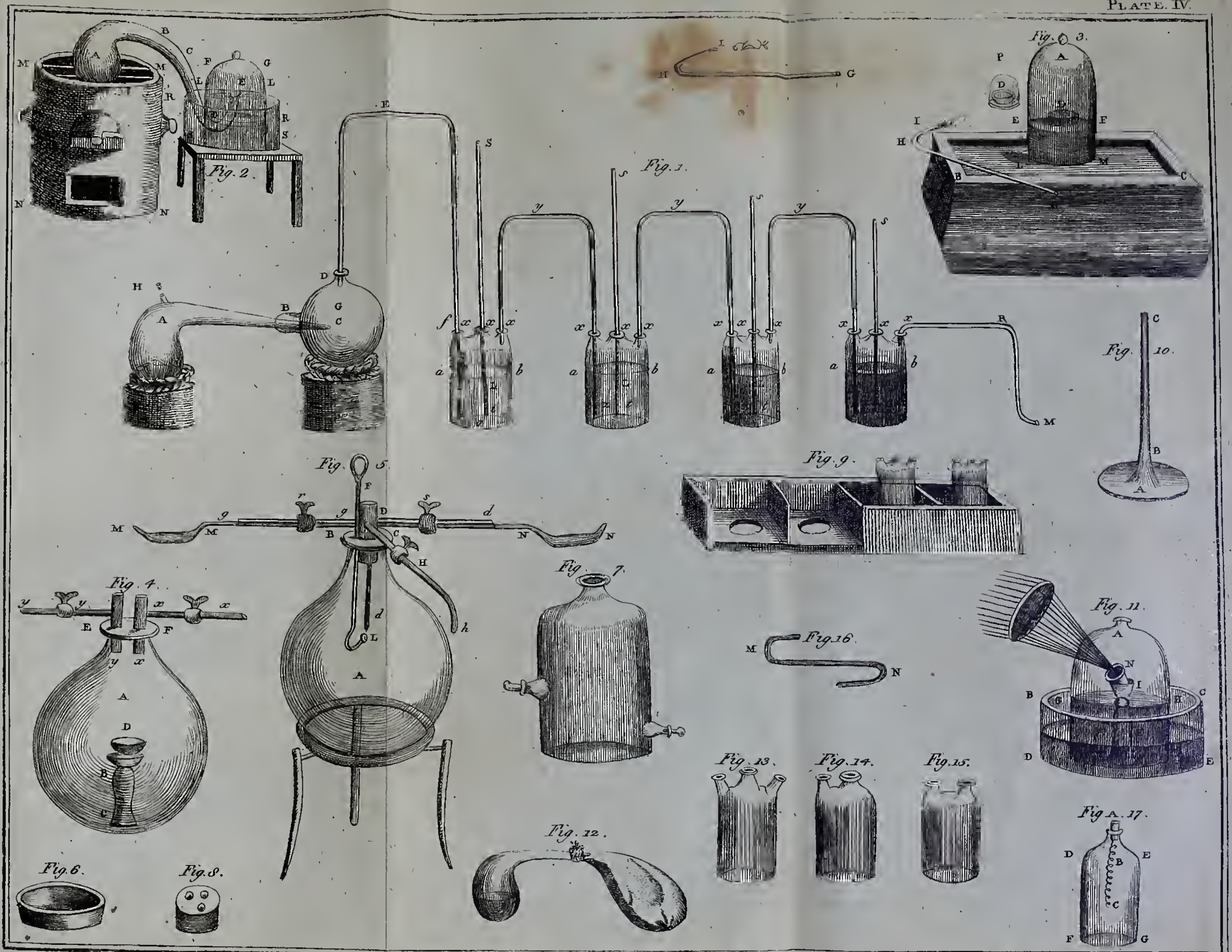
D Lizars Sculpt

PLATE III.



DLizars Sculp^t

PLATE. IV.



D.Lizars Sculpt

Fig. 1.

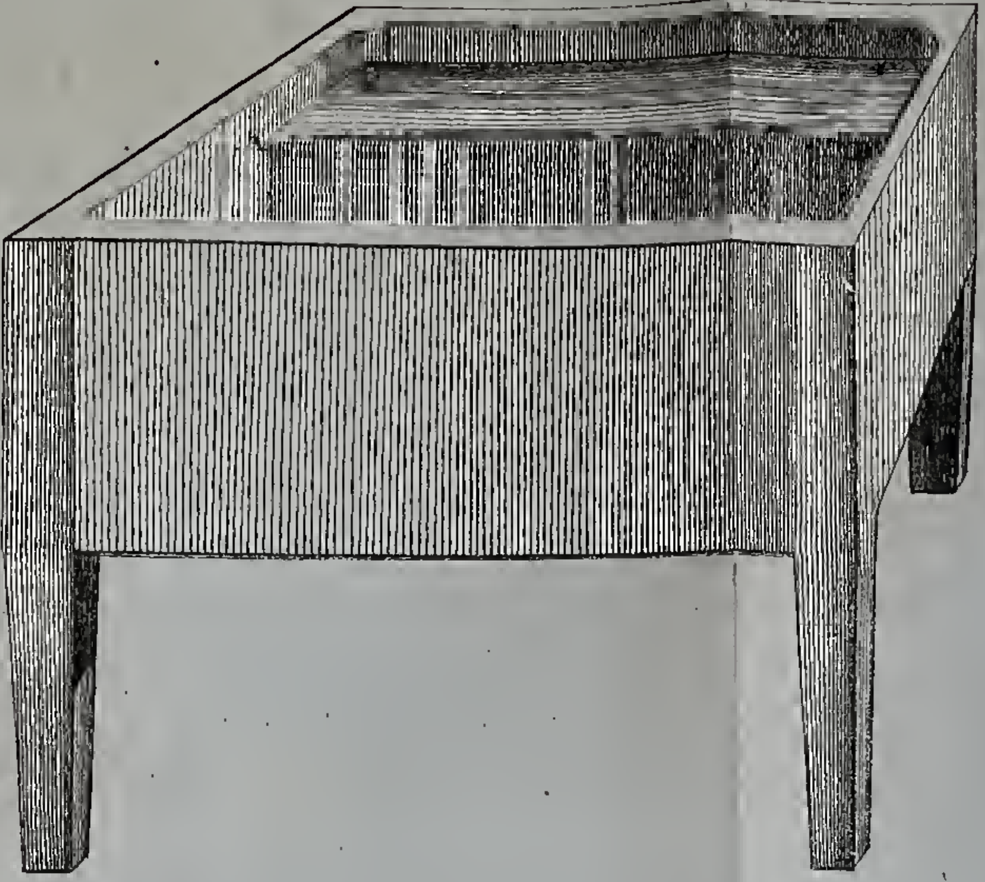


Fig. 2.

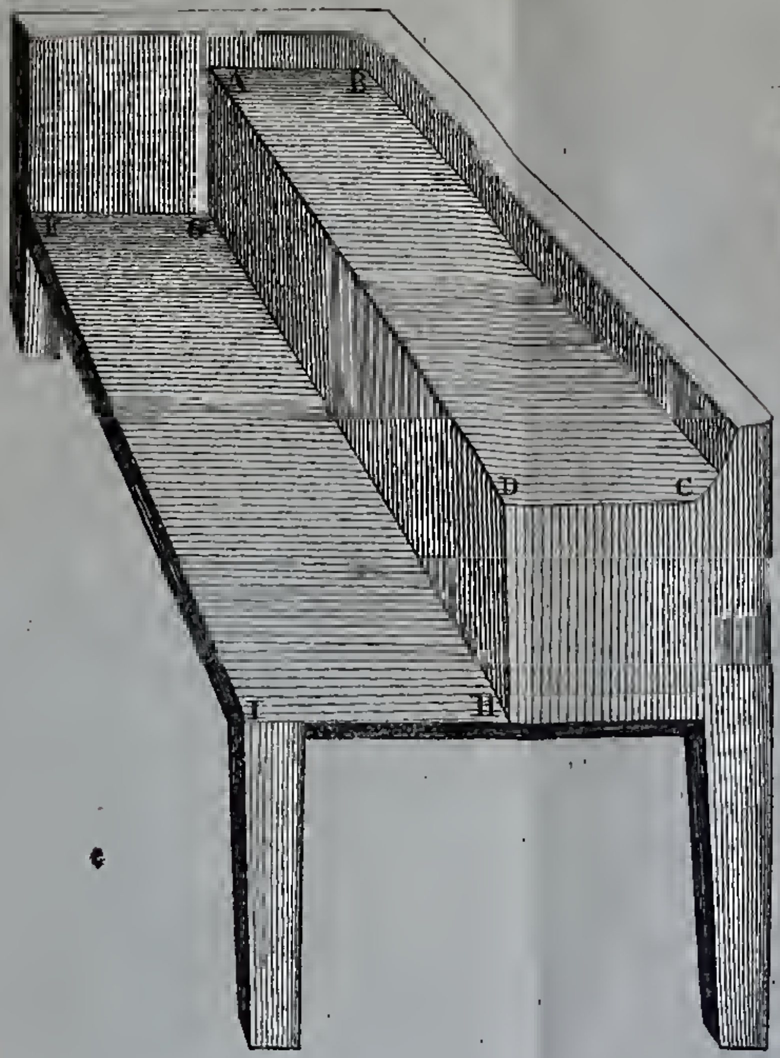


Fig. 8.

Fig. 9.

Fig. 3.

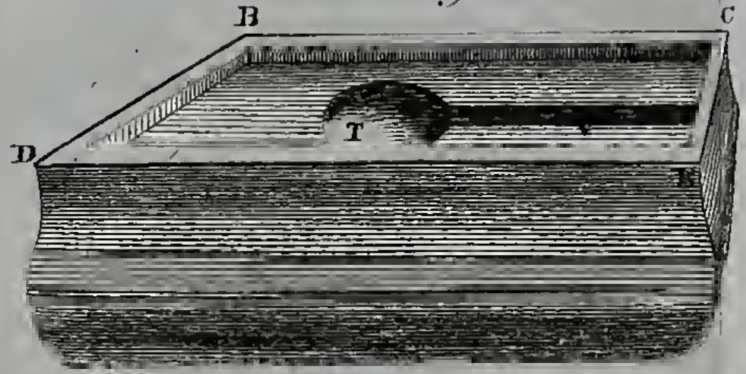


Fig. 5.

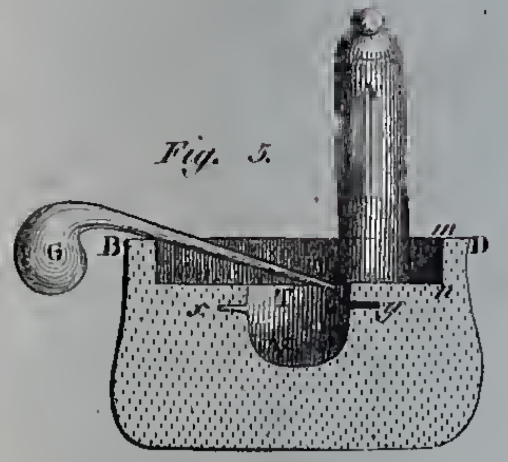


Fig. 6.

Fig. 11.

Fig. 10.

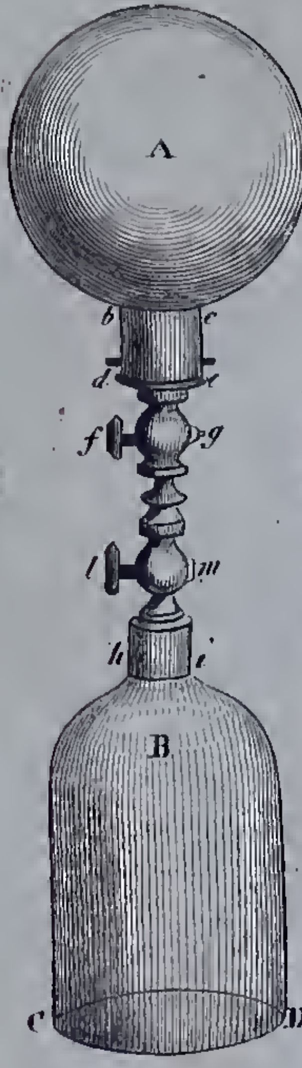
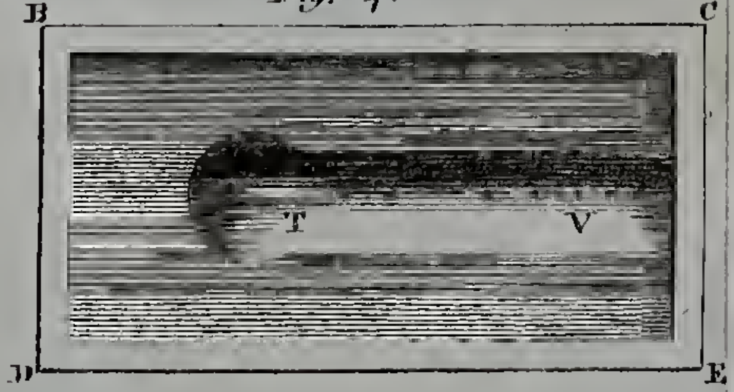


Fig. 12.

Fig. 7.

Fig. 4.



Scale of Feet

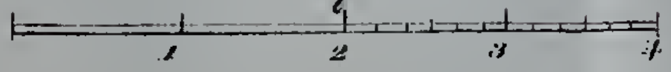
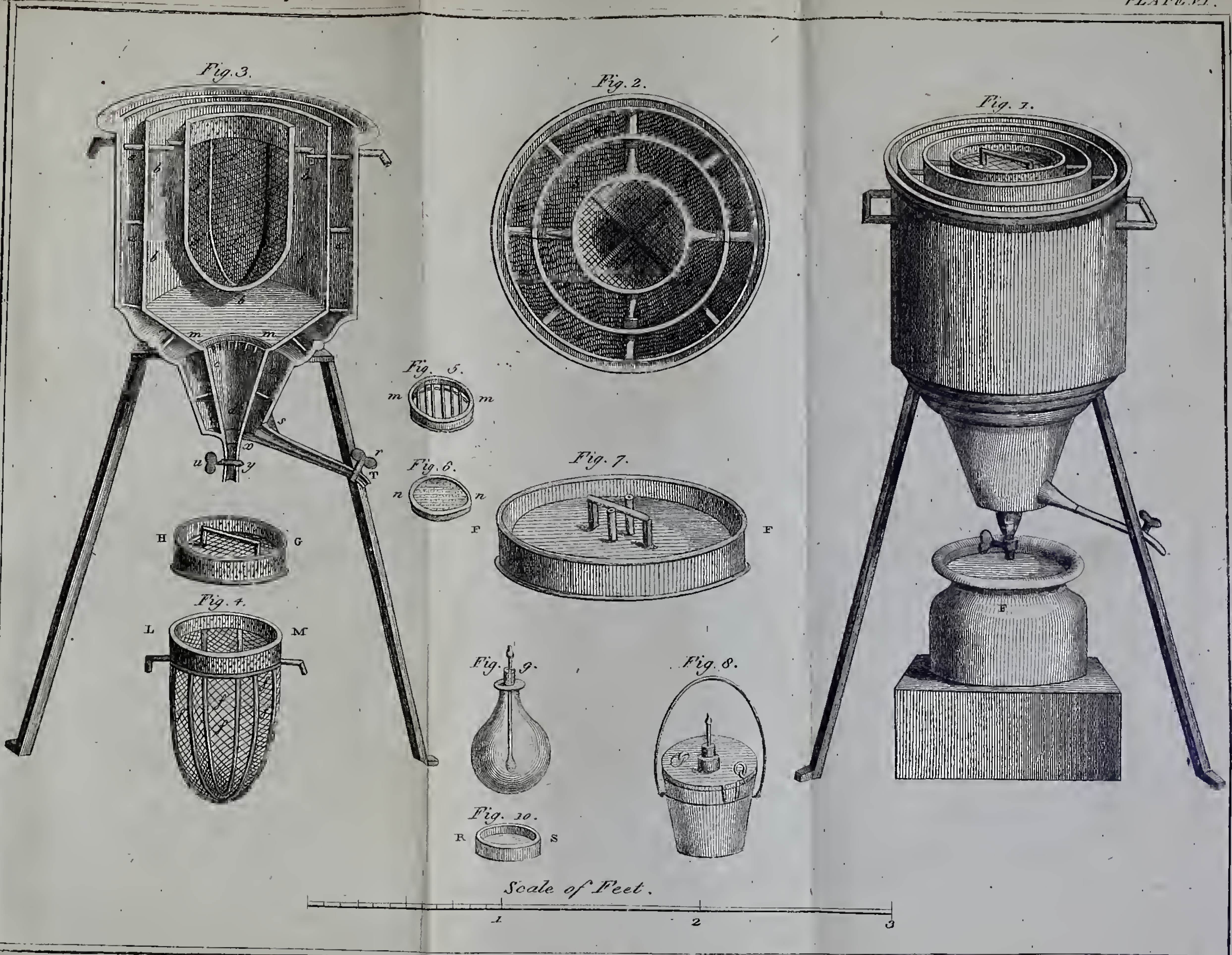
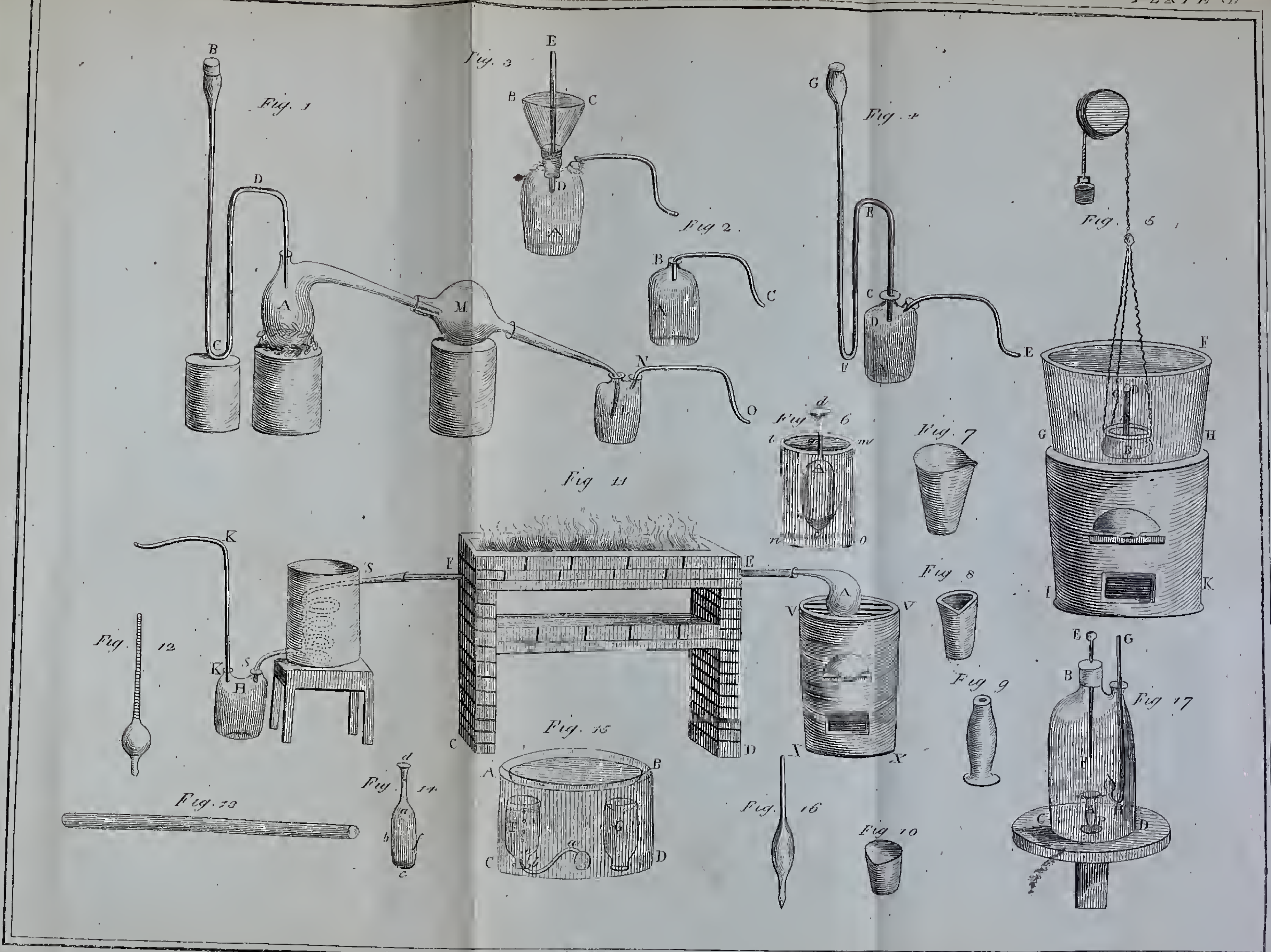


Fig. 13.

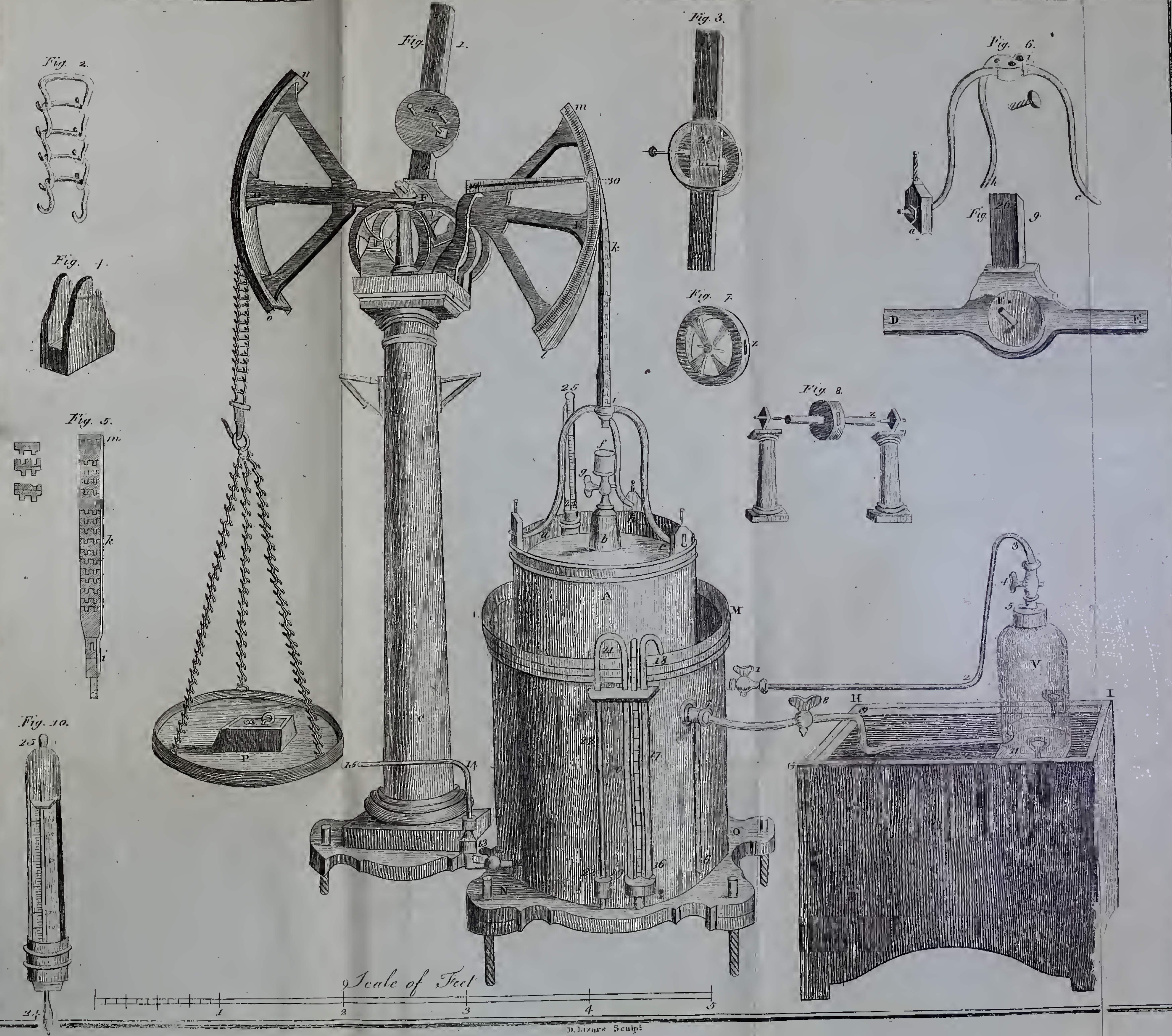
D.Lizars Sculp^t



P. Lizars Sculpt.



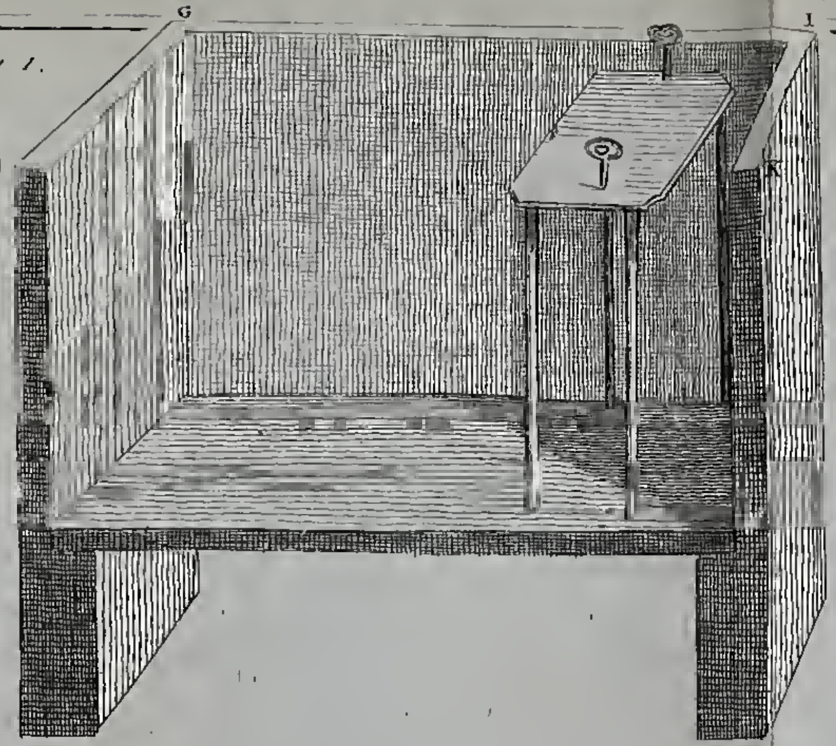
D Lizars Sculp^{t}



D. Lizars Sculpt

PLATE IX.

Fig 1.



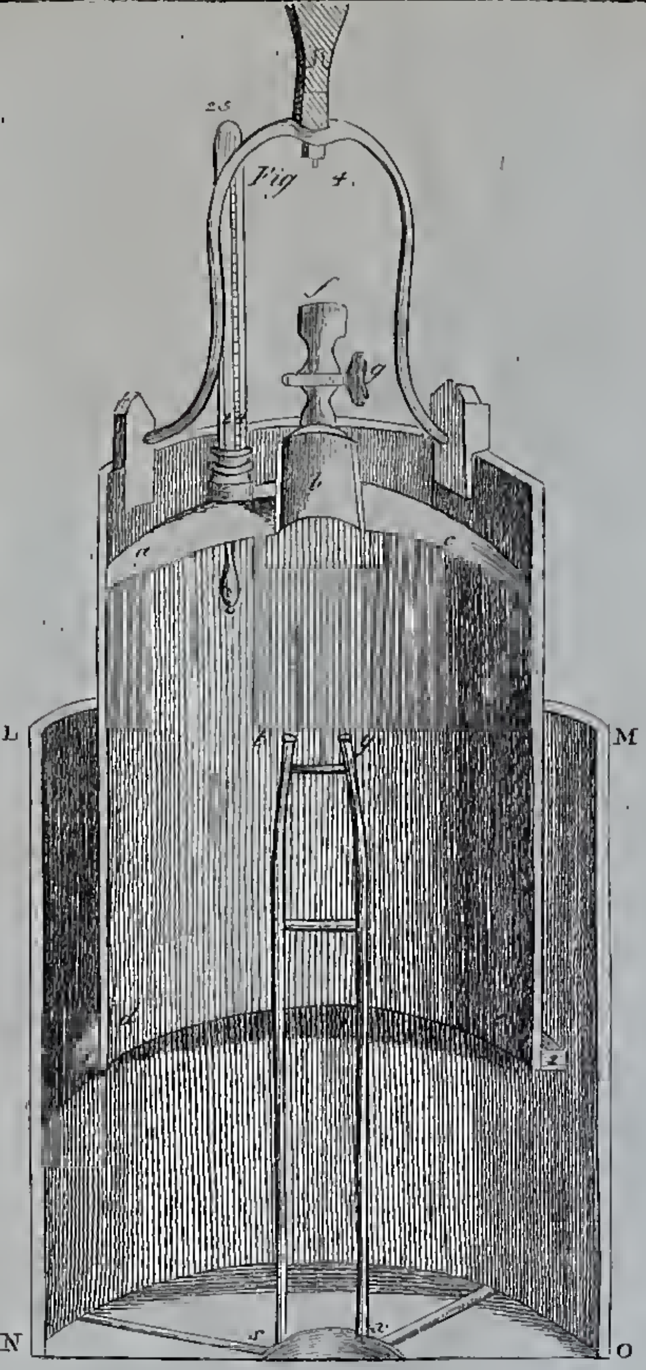


Fig. 3.

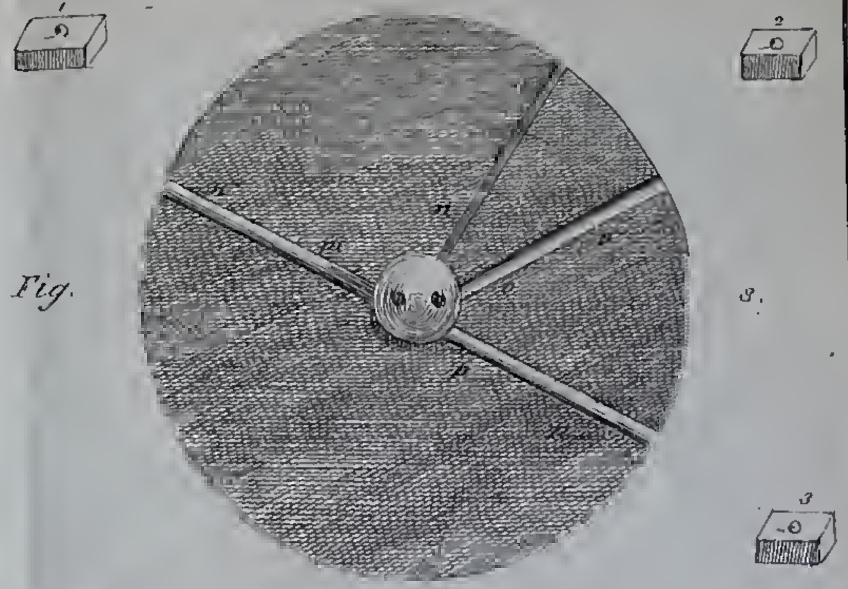


Fig 2.

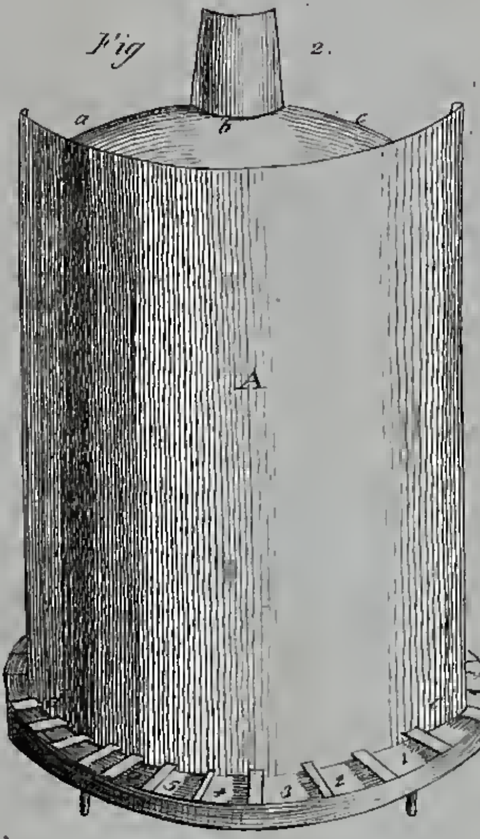
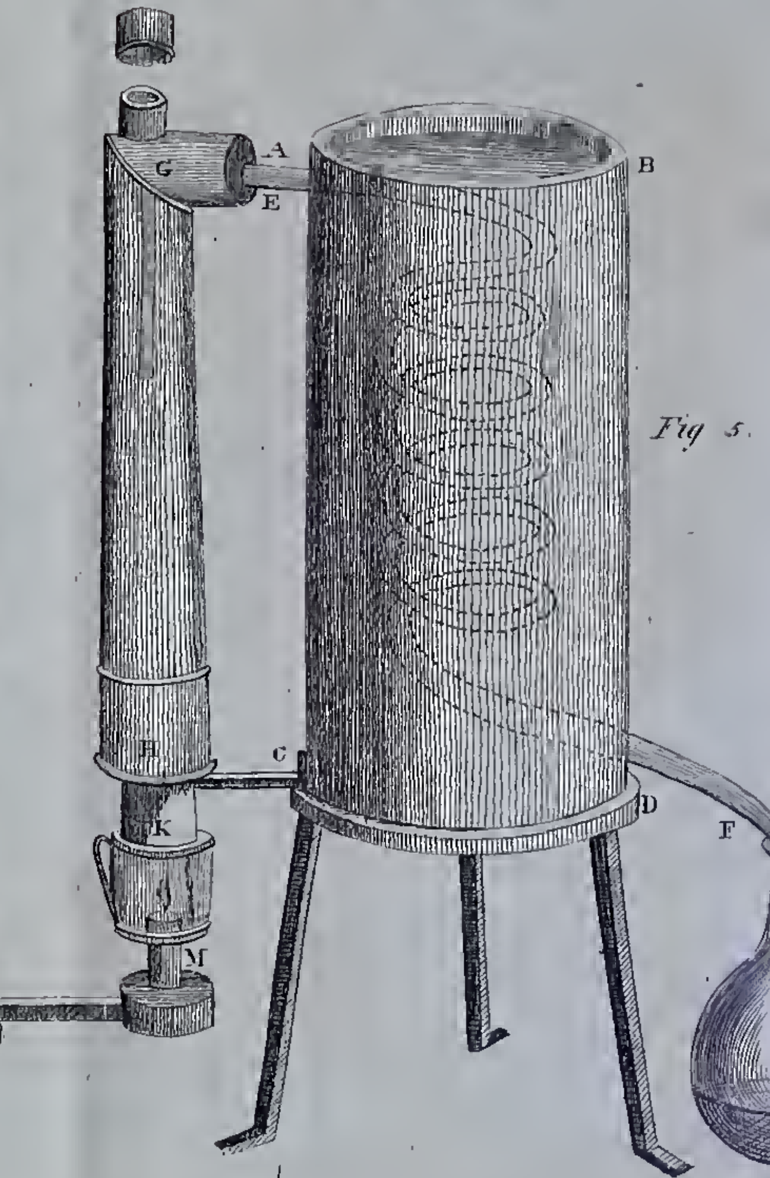
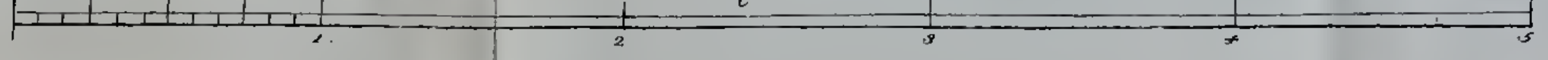


Fig 5.



Scale of Feet

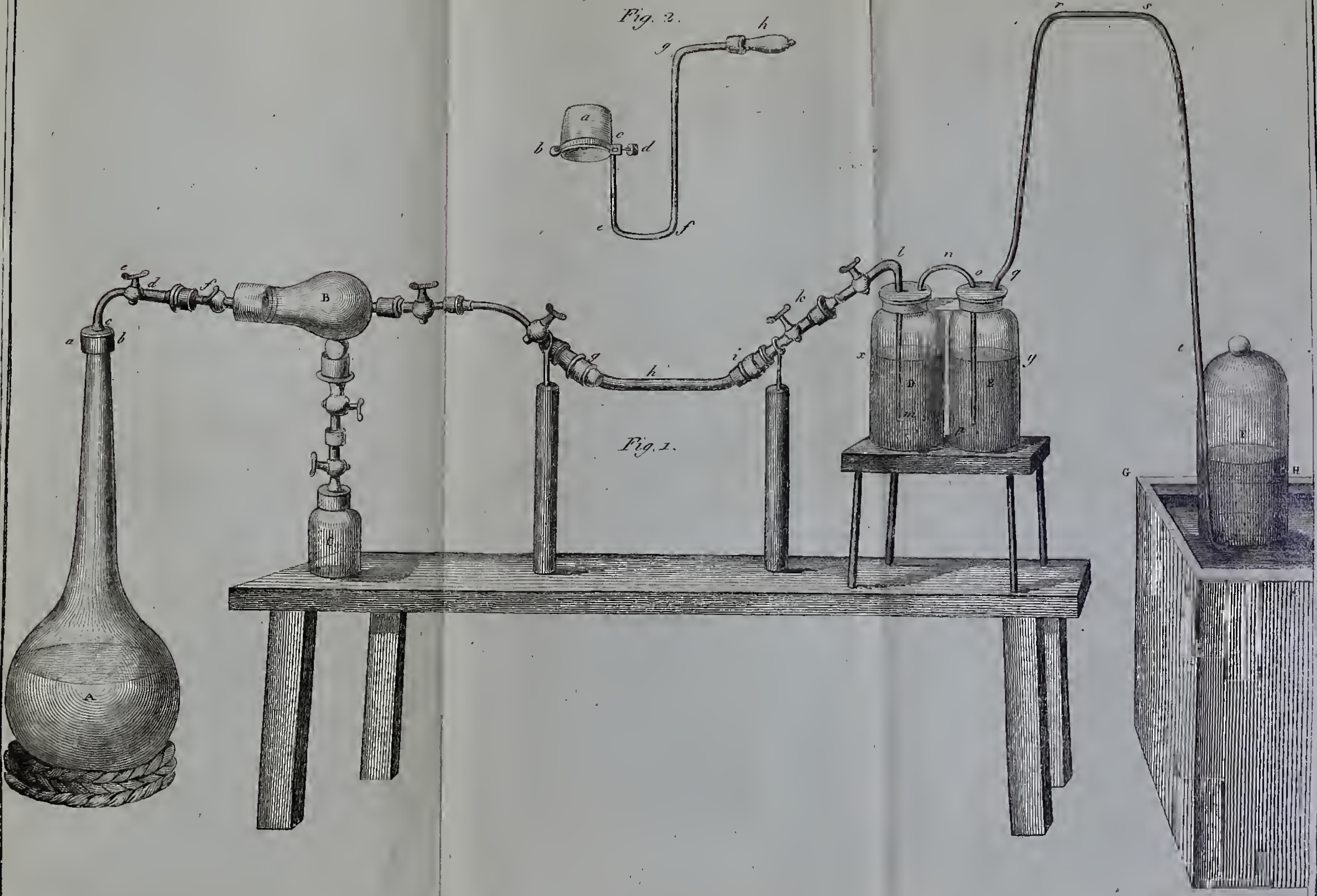


D.Lizars Sculp^t

PLATE X.

Fig. 2.

Fig. 1.



D. Lizars Sculp^t

PLATE XI

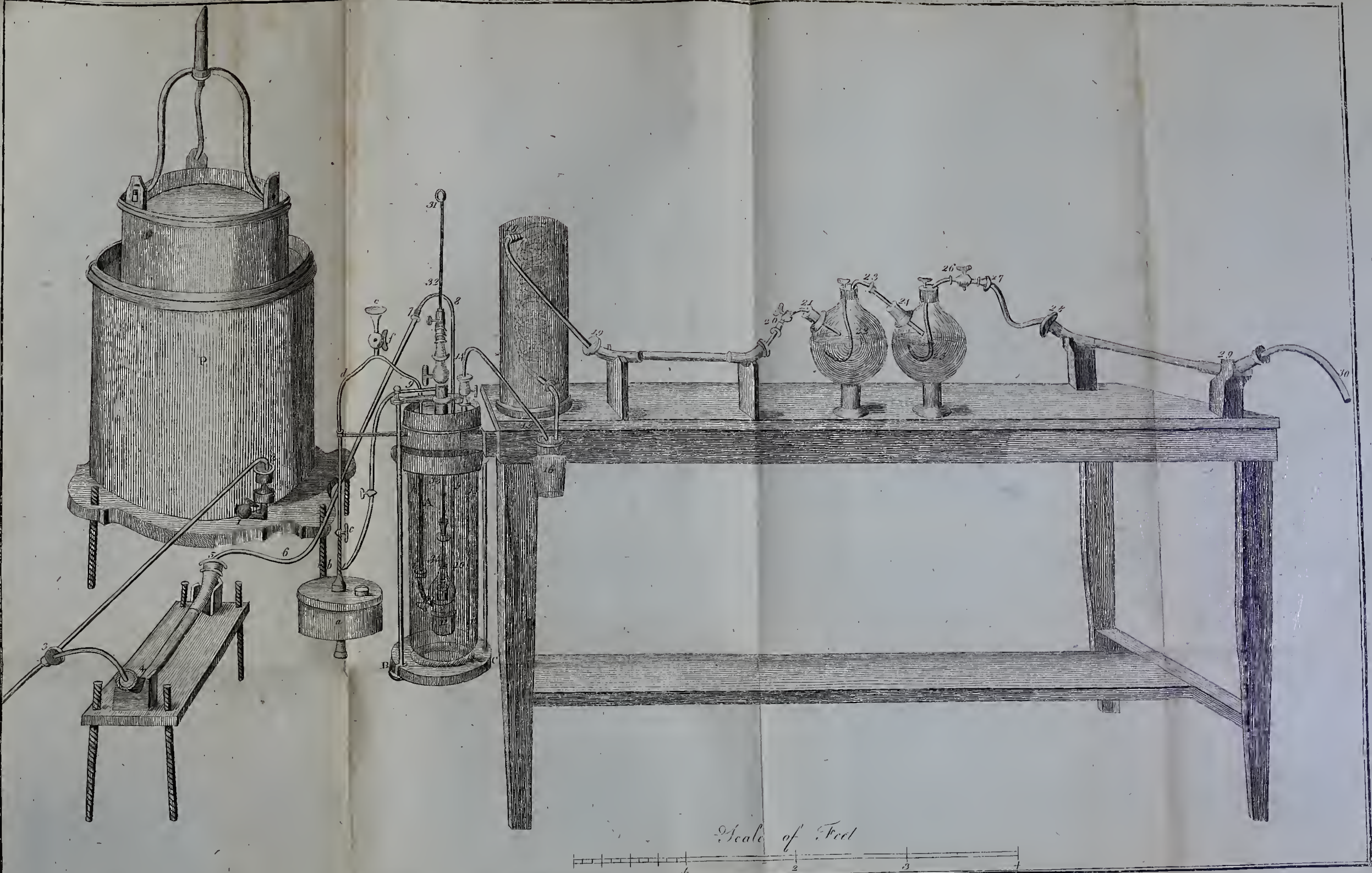
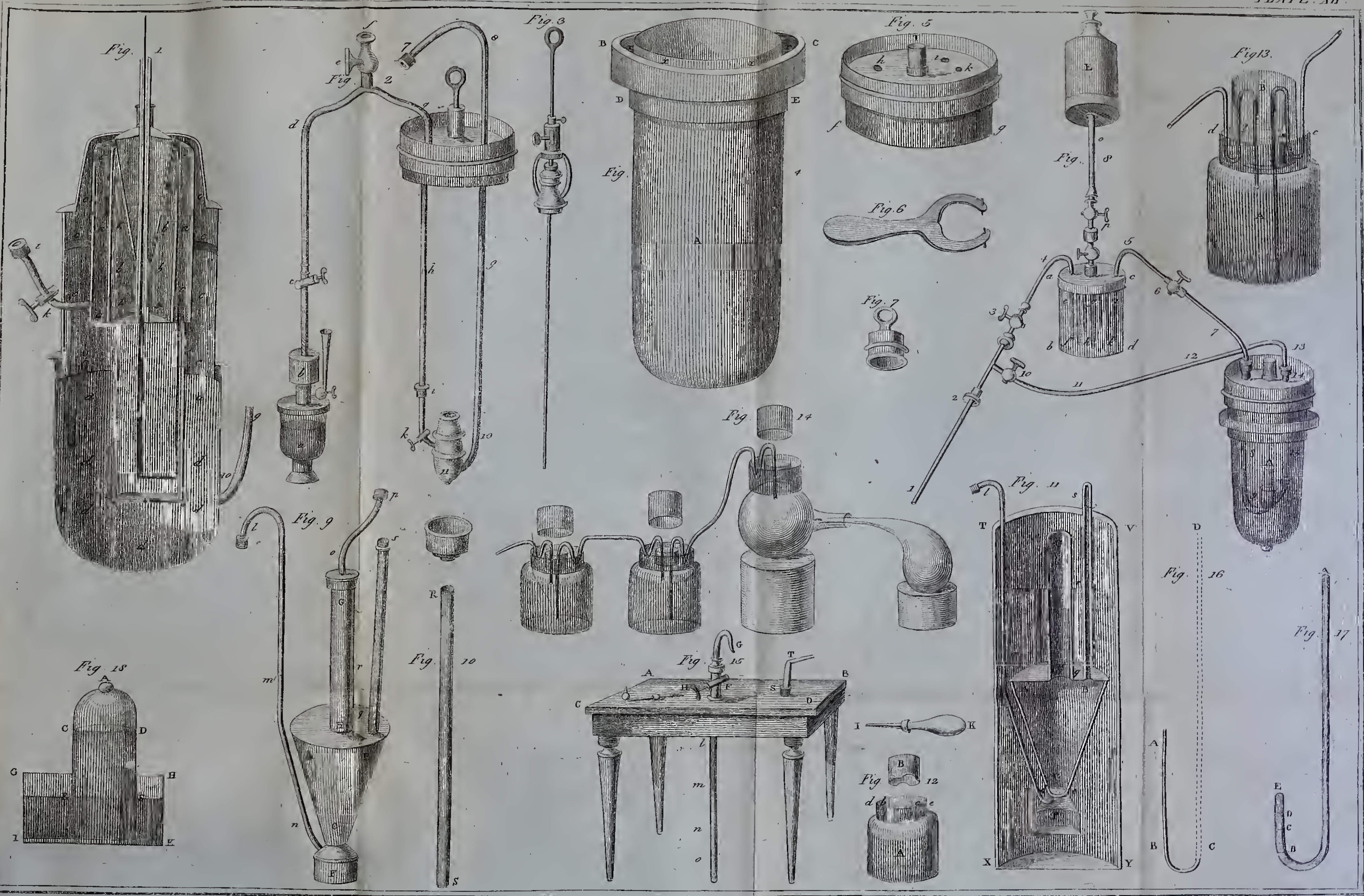

P
1
2
3
4
5
6
7
8
9
a
b
c
d
e
f
A
B
C
14
16
19
20
21
22
23
24
26
27
28
29
30
31
32
Scale of Feet
1
2
3
4

PLATE. XII.



D. Lizars Sculp.

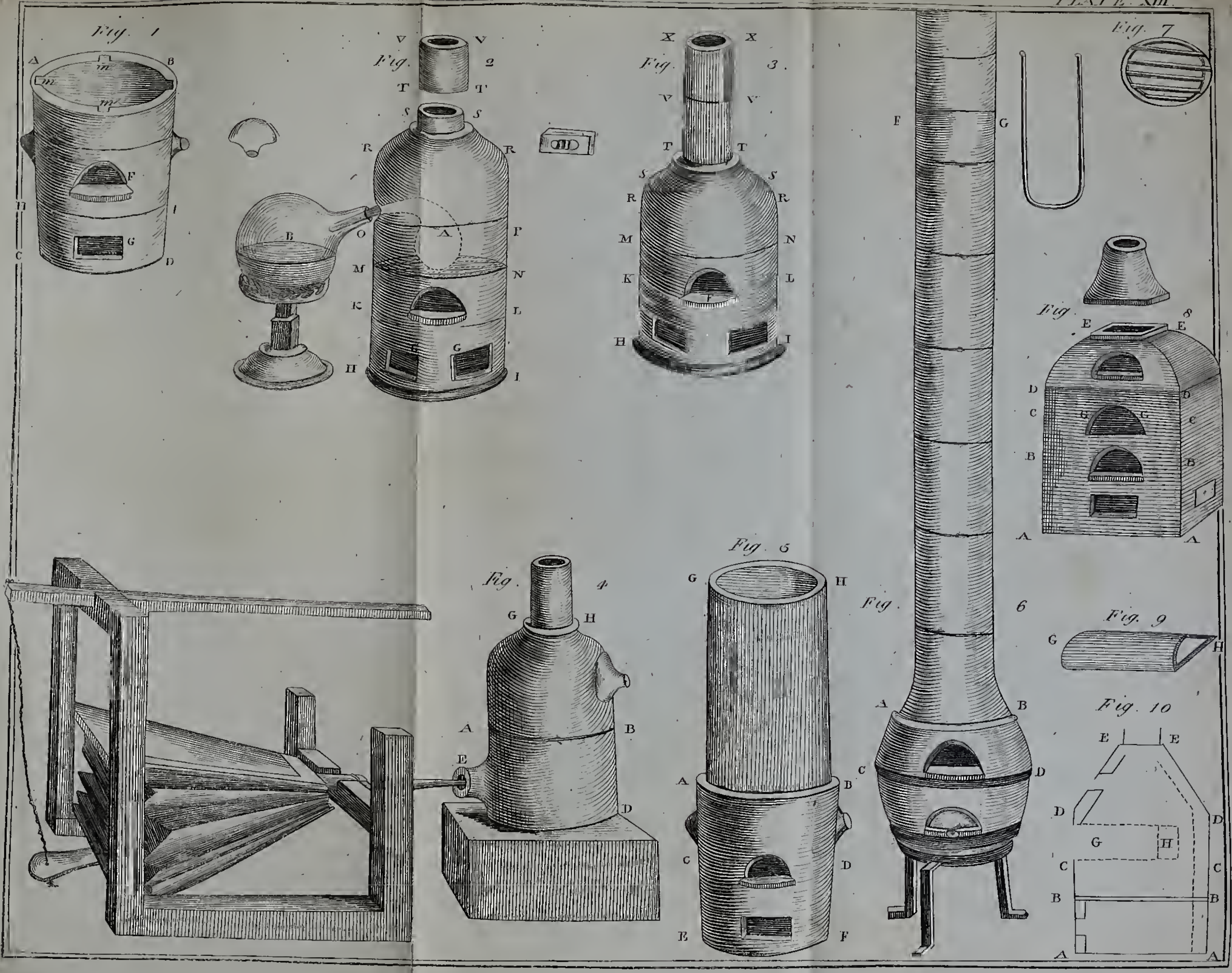


Fig. 1
A
B
m
m
m
F
H
I
C
G
D
Fig. 2
V
V
T
T
S
S
R
R
O
A
P
B
M
N
K
L
H
G
G
I
Fig. 3
X
X
V
V
T
T
S
S
R
R
M
N
K
L
F
H
I
Fig. 4
G
H
A
B
E
D
Fig. 5
G
H
A
B
C
D
E
F
Fig. 6
F
G
A
B
C
D
Fig. 7
Fig. 8
E
E
D
D
C
G
G
C
B
B
A
A
Fig. 9
G
H
Fig. 10
E
E
D
D
G
H
C
C
B
B
A
A

h. 2. 29

background